

01 SOLID FUELS

Sources, winning, properties

15/00001 A review of the correlations of coal properties with elemental composition

Mathews, J. P. *et al. Fuel Processing Technology*, 2014, 121, 104–113. The spatial arrangement and abundance of the elements: C, H, N, O, S often correlate or directly influence a plethora of coal properties. For more than 90 years, attempts have utilized the ultimate (elemental) analysis of coal to predict a wide variety of properties such as: calorific value (higher heating value), volatile matter, vitrinite reflectance (mean maximum), Hardgrove grindability index, helium density, aromaticity, etc. While many relationships resulted in graphical plots that have utility even today, numerical values can also be directly calculated utilizing the correlations. These have the potential to allow rapid predictions and low-cost approaches to coal property determination. Here the many correlations addressing multiple coal properties were reviewed and where possible evaluated against a sampling of the Pennsylvania State University coal sample bank and database for vitrinite-rich (>80% by point counting) US coals. Over 42 correlations were found in the literature. While some correlations, such as calorific value predictions are accurate over a wide range of compositions, others are restricted in applicability to a select rank range. For many correlations, there are challenges to predict the property accurately, over a wide range, but may capture the trends.

15/00002 A universal model of opposed flow combustion of solid fuel over an inert porous medium

Roy, N. C. *et al. Combustion and Flame*, 2014, 161, (6), 1645–1658. In this study, a universal model was developed to examine the behaviour of combustion wave observed in porous solid matters (e.g. smoldering, self-propagating high-temperature synthesis (SHS), diesel particulate filter (DPF) regeneration process). Analytical expressions of the combustion characters of solid combustible (e.g. diesel particulate matters trapped in a DPF) deposited over an inert porous medium were obtained employing large activation energy asymptotic taking into account the sensible transport processes; namely, heat transfer between the porous medium and gas phases, radiation heat transfer from the porous medium, heat loss from the porous medium to the environment, mass transfer of oxygen from the gas stream to the surface of solid fuel and the effective diffusion in modelling the species diffusion. Then the validity of this model was established, in that it was applicable and adaptable for predicting the characteristics of smoldering combustion and thus SHS process. As a result, the features of the combustion wave of the present phenomena would be useful to other processes. From practical point of view and for deep understanding of the behaviour of combustion wave of these processes, the authors investigated the effects of various physical parameters over a wide range of conditions. They also observed that the moving speed of the reaction front increased with the increase of porosity of the porous medium, mass transfer coefficient and initial fuel mass fraction; while it decreased owing to the increase of heat transfer rate from the porous medium to the gas, heat loss to the environment and radiative heat transfer. Furthermore, the results revealed that extinction tends to occur due to lower porosity of the porous medium, higher radiative heat transfer from the porous medium, higher heat transfer rate from the porous medium to the gas and higher heat losses from the porous medium to the environment. Even the observed near-extinction behaviour in reaction front speed versus heat loss diagram is found to be similar what that obtained in a gaseous premixed flame propagating through the porous medium. An extinction limit diagram was presented as a function of radiation-conduction parameter and the gas flow velocity. In addition to this, the impact of radiation and the combined effect of the inclusion of Knudsen diffusion and tortuosity were demonstrated in terms of the spatial temperature and species profiles to examine how these two parameters modify the reaction front structure. Furthermore, the governing equations have been solved numerically and good agreement between the asymptotic and the numerical solution was observed.

15/00003 Effectiveness of catechin and poly(ethylene glycol) at inhibiting the spontaneous combustion of coal

Dou, G. *et al. Fuel Processing Technology*, 2014, 120, 123–127. The effects of various combinations of catechin and poly(ethylene glycol) (PEG) concentrations on the inhibition of coal oxidation were studied. The oxidation behaviours of coal samples both with and without the additives were examined, based on measurements of cross-point temperature, oxygen consumption during low temperature oxidation and carbon monoxide emission rates. The results demon-

strate that an additive consisting of a combination of both catechin and PEG 200 is capable of inhibiting the oxidation process. *In situ* monitoring of the surfaces of coal samples during oxidation also indicated that these additives suppress coal oxidation by accelerating the formation of ether bonds. Accordingly, a suppression mechanism is proposed.

15/00004 Evaluation of catalytic combustion of pulverized coal for use in pulverized coal injection (PCI) and its influence on properties of unburnt chars

Zou, C. *et al. Fuel Processing Technology*, 2014, 119, 136–145. In order to investigate the influences of applying catalysts on pulverized coal injection (PCI) and blast furnace (BF) operations, the catalytic combustion of two kinds of pulverized coals by three oxides (MnO_2 , CaO and Fe_2O_3) was simulated by using a drop tube furnace (DTF), and variation of structures as well as the reactivity of unburnt chars were examined. For bituminous, the relative active sequence of catalysts to the burnout rate was: $\text{CaO} > \text{Fe}_2\text{O}_3 > \text{MnO}_2$. For anthracite, it is as follows: $\text{Fe}_2\text{O}_3 > \text{CaO} > \text{MnO}_2$. These three catalysts exhibited better catalytic effect on anthracite than bituminous coal. In addition, the structural study results imply that the chemical reactions on char particle and pore surface were enhanced greatly by catalysts. On the other hand, the X-ray diffraction analysis shows that chars became more ordered with catalysts addition. Nevertheless, unburnt chars formed from catalytic combustion still have a higher reactivity than pure unburnt char, which is most probably due to the lower activation energy. Consequently, these results imply that the catalytic combustion in PCI operation facilitates the combustion process of pulverized coal in raceway, as well as the following consumption of unburnt char out of raceway.

15/00005 Experimental characterization of a high sulfur Hungarian brown coal for its potential industrial applications

Pettinau, A. *et al. Fuel Processing Technology*, 2014, 122, 1–11. Differently from the conventional combustion and entrained flow gasification technologies, fixed-bed up-draft gasification process tested in pilot scale appears very suitable for the ‘multipurpose transformation’ of Hungarian low-rank and high sulfur brown coal (for the production of electrical energy, heat and eventually gaseous or liquid fuels). This paper presents the positive results of the wide-range analysis (led jointly by Sotacarbo in Italy and by Ormoszén in Hungary) on the possibility to use the Hungarian coal from the north-east basins for energy purposes. At this stage, there is no scientific literature on this subject (the energetic use of this fuel, which is very complex in conventional power generation plants), whereas there are several studies on the geological properties of the Hungarian brown coal and on the energetic exploitation of the Mecsek basin’s high-rank coal. In addition to the conventional characterization (proximate, ultimate and thermal analyses), a series of bench-scale experimental tests were carried out to preliminary assess the combustion performance of Hungarian brown coal and to set a pilot-scale experimentation in the Sotacarbo gasification pilot plant. As results from the experimental tests, the air-blown up-draft gasification of about 11 kg/h of Hungarian brown coal allows to produce about 24–25 kg/h of raw syngas, characterized by a lower heating value of 3.55 MJ/kg. The high sulfur content in primary fuel is one of the main problems when that coal is used. As a matter of fact, conventional cold gas desulfurization processes are typically not sufficient for an efficient syngas desulfurization. But a very high H_2S and COS removal efficiency has been experimentally obtained treating syngas with a zinc oxide-based hot gas desulfurization system. This process allowed to obtain a final H_2S and COS global concentration lower than 20 ppm (by volume), operating at about 400 °C.

15/00006 Structural characterization of the thermal extracts of lignite

Wang, Z. *et al. Fuel Processing Technology*, 2014, 120, 8–15. Thermal extraction (TE) with non-specific solvent at high temperature is a potential technology to separate organic materials from coal, especially low-rank coal such as lignite. In this paper, thermal extract (TES) of Xianfeng lignite (XL) in toluene/methanol (3:1, volume) mixed solvent at 300 °C was separated into different sub-fractions by the method of column chromatography combined with Soxhlet extraction in tetrahydrofuran (THF). These sub-fractions were characterized by element analysis, Fourier transform infrared spectroscopy, ^1H NMR and gas chromatography–mass spectrometry. Seventy-eight compounds including C_{12-30} higher aliphatic hydrocarbons (HAHs), aromatic hydrocarbons (AHs), C_{17-27} fatty acid methyl esters (FAMES) and other heteroatomic compounds were identified from the TES. As two groups of predominant components, HAHs and FAMES are the intrinsic components in XL except for small amount of FAMES produced by esterification and transesterification reactions in the TE process. Further, the mechanism of TE was also speculated by the characterization results of TES. As a result, the TE with non-

specific solvent at high temperature can not only improve the extract yield of organic materials, but also obtain chemicals such as HAHs and FAMES from lignite.

15/00007 Transported PDF modeling of pulverized coal jet flames

Zhao, X.-Y. and Haworth, D. C. *Combustion and Flame*, 2014, 161, (7), 1866–1882.

A transported composition probability density function (PDF) method is developed for pulverized coal combustion. A consistent hybrid Lagrangian particle/Eulerian mesh algorithm is used to solve the modelled PDF transport equation for the gas phase, with finite-rate gas-phase chemistry. The model includes $k-\epsilon$ turbulence, gradient transport for scalars, and a Euclidean minimum spanning tree mixing model. A separate Lagrangian description is used to solve for the coal particle phase, including particle tracking, coal devolatilization and surface reaction models. Interphase coupling models are developed to handle the interaction between the gas phase and the solid phase. Radiative heat transfer is modeled by a PIP1 model for a gray absorbing emitting and scattering gas-particle system. Two independent laboratory-scale pulverized coal jet flames ('flame A' and 'flame B') are simulated using the new model. For flame A, the baseline model reproduces the measured mean and RMS particle axial velocity reasonably well. Some discrepancies are found in particle temperature and gas-phase concentrations, which may in part be due to the uncertainties in the experimental data. Sensitivities of model results to coal-related model variations, turbulence-chemistry interactions, different interphase coupling strategies, and finite-rate chemistry are explored to establish sensitivities and to determine which aspects of the models are most important. The same model is applied to a second flame (flame B), the only change being in parameters related to the different coal composition. It is found that experimental standoff heights cannot be reproduced for three different stoichiometric ratios using a single model. Time scales for chemical reactions, devolatilization and turbulence are extracted and compared, to study the level of turbulence-chemistry-particle interactions in flame A and to test the popular assumption of equilibrium chemistry in coal combustion modeling. Mixture-fraction statistics for flame B are explored to test assumptions that have been proposed for mixture-fraction-based coal models. While the usual assumption of Beta distributions is found to be appropriate, assumptions of statistical independence of two mixture fractions are not valid.

Preparation

15/00008 A kinetic study of microwave and fluidized-bed drying of a Chinese lignite

Tahmasebi, A. *et al. Chemical Engineering Research and Design*, 2014, 92, (1), 54–65.

The drying kinetics of Chinese lignite in nitrogen fluidized-bed, superheated steam fluidized-bed and microwave were investigated. The changes in the mass as a function of drying time were measured under various drying conditions. The variations of moisture ratio with time were used to test 10 different thin-layer empirical drying models given in the literature. In studying the consistency of all the models, some statistical tests, such as χ^2 , residual sum of squares (RSS) and F -value were also used as well as coefficient of determination R^2 . In nitrogen fluidized-bed and superheated steam fluidized-bed, the Midilli-Kucuk model best described the lignite drying process. Drying data in microwave were best described by the Page model, indicative of a difference in kinetics between the two drying methods. This difference was attributed to different heat transfer mechanisms under conventional and microwave drying conditions. The effects of drying parameters in nitrogen fluidized-bed, superheated steam fluidized-bed and microwave drying on the constants and coefficients of the selected models were studied by multiple regression analysis. The apparent diffusion coefficient of moisture in samples was obtained from the kinetics data and the apparent activation energies under nitrogen fluidized-bed, superheated steam fluidized-bed and microwave drying were found to be rather similar.

15/00009 Participation of large particles in coal dust explosions

Man, C. K. and Harris, M. L. *Journal of Loss Prevention in the Process Industries*, 2014, 27, 49–54.

Float coal dust is produced during the coal mining process in underground mines. If it is entrained, the float coal dust presents a dangerous explosion hazard to miners when it reaches the minimum explosible concentration and is ignited. However, coal dust can be inerted if properly mixed with generous amounts of pulverized rock dust such as limestone to result in a homogeneous dust mixture with a

total incombustible content (TIC) $\geq 80\%$. In the United States, it is mandatory for the rock dust to be 100% passing through a 20 mesh (841 μm) sieve and 70% or more passing through a 200 mesh (75 μm) sieve. Laboratory experiments have been conducted using the National Institute for Occupational Safety and Health Office of Mine Safety and Health Research 20-L and the Fike Corporation 1-m³ explosion chambers. Coal and rock dust samples were prepared by sieving and were used to investigate the effect of particle size on explosibility and inerting effectiveness. The results from both chambers show that large coal particles >60 mesh ($>250 \mu\text{m}$) do not explode/ignite at dust concentrations up to 600 g/m³, and limestone rock dust particles >200 mesh ($>75 \mu\text{m}$) require a significantly higher TIC of 90% to inert Pittsburgh pulverized coal. This data illustrates the significance of particle size for preventing coal dust explosions and the importance of measuring particle size as well as TIC (which includes moisture as well as incombustibles) to determine the true explosibility of a dust sample.

15/00010 Release of pollutant components in CLC of lignite

Mendiara, T. *et al. International Journal of Greenhouse Gas Control*, 2014, 22, 15–24.

The recently developed chemical looping combustion technology (CLC) is nowadays considered an interesting option to capture CO₂ at low cost in fossil fuelled power plants. In the past few years, significant advances have been achieved in the combustion of both gaseous and solid fuels. Nevertheless, pollutant gas emissions from CLC systems have received little attention. This paper focuses on sulfur, nitrogen and mercury emissions during lignite combustion in a 500 W_{th} CLC unit. Ilmenite was used as oxygen carrier, as it is one of the most common materials used for CLC of solid fuels. The main sulfur species detected in the fuel reactor were H₂S and SO₂. The amount and proportion depended on the temperature of the fuel reactor. The higher the temperature, the more H₂S converted to SO₂. In the air reactor, the sulfur in the unconverted char was released as SO₂. Regarding the emission of nitrogen in coal, most of the nitrogen was found as N₂ at the outlet of the fuel reactor. No NH₃ or HCN were registered and only small amounts of NO were detected. The nitrogen contained in the char reaching the air reactor was released as NO. Mercury speciation was also analysed and the ratio Hg²⁺/Hg⁰ determined. In the fuel reactor, the major mercury species was Hg⁰ and in the air reactor Hg²⁺. The incorporation of a carbon separation unit between fuel and air reactors would help to reduce the sulfur emissions in the air reactor and comply with the current legislation for power generation systems.

15/00011 The release of mercury from Polish coals during thermal treatment of fuels in a fluidized bed reactor

Wichliński, M. *et al. Fuel Processing Technology*, 2014, 119, 92–97.

The paper deals with mercury release during thermal treatment of Polish coals. Three coal types (two hard coals and a lignite) from Polish coal mines supplying fuel for the power generation industry were used in the experiment. The release of mercury was investigated in a fluidized bed reactor heated to moderate temperatures 170–410 °C. The thermal treatment of mercury was conducted in various atmospheres (air, nitrogen and carbon dioxide). Except for mercury concentration in the flue gas the emission of CO, CO₂ and O₂ was also determined. The experimental results indicated that the mercury release from hard coals strongly depended on the gas atmosphere. The highest mercury release was determined in CO₂ atmosphere, while the Hg release in air or nitrogen gas was significantly lower. In the case of lignite no effect of gas type on the mercury release was stated. The results of the investigation also indicated that regardless of the coal type and the process temperature the loss of chemical energy of the coal samples, calculated from the emission of CO and CO₂ was less than 5%.

Economics, business, marketing, policy

15/00012 Pathological study of the prevalence of silicosis among coal miners in Iran: a case history

Naghadehi, M. Z. *et al. Atmospheric Environment*, 2014, 83, 1–5.

One of the most hazardous diseases that is commonly associated with the coal mining industry is silicosis, which caused by dust inhalation. This disease occurs as a result of prolonged breathing of dust containing silica (quartz). The generation of coalmine dust during underground and surface coal mining is the most significant source of coal dust exposure. Silica dust develops scar tissue inside the lungs which reduces the lungs ability to extract oxygen from the air. All miners working in underground and surface coal mines are at risk of being exposed to mine dust containing silica. In this study, cases with pathologic diagnosis of silicosis over a 7-year period between 2000 and

2007 were retrieved from the pathologic file of Department of Pathology, Massih Daneshvary Hospital in Iran. Results of this case study showed the great effects of dust exposure and inhalation from the viewpoint of symptoms especially between the miners.

15/00013 Rates of low-pH biological Fe(II) oxidation in the Appalachian bituminous coal basin and the Iberian pyrite belt

Larson, L. N. *et al. Applied Geochemistry*, 2014, 47, 85–98.
Low-pH Fe(II) oxidation can be exploited for the treatment of acid mine drainage (AMD). However, natural or engineered terraced iron formations (TIFs) are underutilized for AMD treatment because of uncertainties with respect to treatment performance. To address this problem, the rates of Fe(II) oxidation were measured multiple times at eight sites in the Appalachian bituminous coal basin and at three sites in the Iberian pyrite belt (IPB). Longitudinal geochemical transects were measured downstream of emergent anoxic AMD sources. Water velocities were measured at each sampling location and used to transform concentration versus distance profiles into concentration versus travel time for kinetic analysis of field data. Zero-order Fe(II) oxidation rates ranged from 8.60 to $81.3 \times 10^{-7} \text{ mol L}^{-1} \text{ s}^{-1}$ at the Appalachian sites and 13.1 to $67.9 \times 10^{-7} \text{ mol L}^{-1} \text{ s}^{-1}$ at the IPB sites. First-order Fe(II) oxidation rate constants ranged from 0.035 to 0.399 min^{-1} at the Appalachian sites and 0.003 to 0.010 min^{-1} at the IPB sites. Faster rates of Fe(II) oxidation were measured at two sites (one in Appalachia and one in IPB) where the emergent pH values were the lowest and little to no oxidative precipitation of Fe(III) occurred. Laboratory-based rates of Fe(II) oxidation were measured with TIF sediments and emergent AMD collected from seven Appalachian sites. First-order laboratory rate constants normalized to sediment biomass concentrations (measured by phospholipid fatty acids; PLFA) were positively correlated to first-order field rate constants. Biomass composition was relatively similar between all sites, and predominately comprised of proteobacteria and general PLFAs. A zero-order lab-based removal rate for dissolved Fe(T) was used to calculate area-based design criteria of 2.6 – $8.7 \text{ g Fe day}^{-1} \text{ m}^{-2}$ (GDM) for both natural and engineered TIFs.

15/00014 Transport of organic contaminants mobilized from coal through sandstone overlying a geological carbon sequestration reservoir

Zhong, L. *et al. International Journal of Greenhouse Gas Control*, 2014, 21, 158–164.

Successful implementation of large-scale carbon capture and storage within deep geologic reservoirs will require public acceptance of the associated environmental risks. In order for this to occur, a better understanding of these risks must be developed. An important risk factor associated with deep geologic storage of CO_2 is the potential for leakage of fluids from the storage reservoir that could potentially impact valuable groundwater resources that overlie the storage reservoir. The research described here is focused on the transport and fate of toxic organic compounds mobilized by supercritical carbon dioxide (scCO_2) from organic rich storage reservoirs such as unmineable coal seams and depleted oil reservoirs. Column experiments were conducted using a water wetted sandstone core installed in a tri-axial core holder to study the potential for toxic organic compounds mobilized from coal by scCO_2 under simulated geologic carbon storage conditions to impact groundwater. Rock core effluent pressures were set at 0, 500, or 1000 psig and the core temperature was set at 20 or 50°C to simulate the transport at different subsurface depths. The concentrations of the organic compounds in the column effluent and their distribution within the sandstone core were monitored. Results indicate that the mobility through the core sample was much higher for BTEX compounds than for naphthalene. Retention of organic compounds from the vapour phase to the core appeared to be primarily controlled by partitioning from the vapour phase to the aqueous phase. Adsorption to the surfaces of the wetted sandstone was also significant for naphthalene. Reduced temperature and elevated pressure resulted in greater partitioning of the mobilized organic contaminants into the pore water.

Derived solid fuels

15/00015 A statistical analysis of the auto thermal fast pyrolysis of elephant grass in fluidized bed reactor based on produced charcoal

Mesa-Pérez, J. M. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 322–329.

This research presents and discusses the results of product yields, higher heating value, proximate and ultimate analyses of the charcoal obtained in the fast pyrolysis plant – PPR-200. It is a fast pyrolysis plant

with a biomass feed capacity of 200 kg/hour, owned by Unicamp. Elephant grass with an average particle diameter of 2 mm and 12% moisture was used as raw material. The PPR-200 facility operated under different conditions. Air was used as fluidization agent. This study tries to increase the knowledge of the PPR-200 plant operation in fast pyrolysis regimen. Experimental tests were carried out considering two independent factors: fluidization air and stoichiometric air ratio and the height of the fixed bed. In the pyrolysis process, a charcoal with a high carbon content is obtained as well as the release of oxygen from the biomass. Experimental results showed that the favourable operating conditions for oxygen release from elephant grass and carbon concentration in the charcoal are a fixed fluidized bed of 207 mm height and 8% of supplied air to the stoichiometric air ratio. Under these optimized conditions, the fluidized bed temperature resulted to be 650°C on average and the yield production of charcoal in relation to the biomass fed (dry and ash free) was of 14 wt%. The charcoal produced under such conditions presented 92.4% of elemental carbon, and 2.85% of elemental oxygen.

15/00016 Catalytic upgrading of coal pyrolysis tar over char-based catalysts

Han, J. *et al. Fuel Processing Technology*, 2014, 122, 98–106.

Catalytic upgrading of coal pyrolysis tar was investigated in a dual-stage reactor over char and metal-impregnated char (Co-char, Ni-char, Cu-char, Zn-char). The catalytic upgrading caused the lower total tar yield and the higher non-condensable gas yield but the fraction of light tar (boiling point $<360^\circ\text{C}$) obviously increased to allow slightly higher total yield of light tar. When the catalytic upgrading was at 600°C over a layer of char having a mass of 20% of the tested coal, the resulting light tar fraction in the tar increased by 25% in comparison with the coal pyrolysis only at 600°C . Over the metal-impregnated char, which was 5% of the tested coal in mass, good upgrading effect was obtained at 500°C . The catalytic tar-upgrading activity decreased in an order of Co-char $>$ Ni-char $>$ Cu-char $>$ Zn-char, and over Ni-char the realized light tar yield and its content in the tar increased by 17.2% and 32.7%, respectively. The upgrading effect also lowered the contents of element N and S in the resulting tar by 45.6% and 43.5%, respectively. NH_3 -temperature programmed desorption clarified that the order in acidity of the char-based catalysts was the same as for the upgrading activity.

15/00017 Flow boiling heat transfer enhancement using carbon nanotube coatings

Sujith Kumar, C. S. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 166–175.

This study investigated the effect of carbon nanotubes (CNTs) and diamond coating over copper substrates on flow boiling heat transfer performance. Using demineralized water as the working fluid, heat transfer experiments were conducted in a mini-channel with an overall dimension of $25 \times 20 \times 0.4 \text{ mm}^3$. Each of the coated surfaces was tested repeatedly at different velocities to explore the dependence of heat transfer performance on parameters, especially the critical heat flux (CHF). The effect of wettability of the surface on flow boiling heat transfer was also studied. A remarkable increase in the critical heat flux was observed on CNT-coated surface when compared with bare Cu or diamond coated Cu substrate. An enhancement of 21.6% in the CHF was observed for a mass flux of $283 \text{ kg/m}^2 \text{ s}$.

15/00018 Improvement of carbon nanotube stability by high temperature oxygen/chlorine gas treatment

Desforjes, A. *et al. Carbon*, 2014, 76, 275–284.

Carbon nanotubes are interesting for applications in numerous fields. Nevertheless the as-produced samples prepared from bulk synthesis methods contain impurities and remain entangled if neither mechanical nor chemical treatment is applied. Such treatments are known to damage the carbon nanotube structure and to reduce their stability which induces drastic diminution of their properties. The authors have developed a purification method based on the use of a gas-phase treatment under an oxygen/chlorine mixture at high temperature (around 1000°C). The authors were able to efficiently remove metal-based impurities from catalyst residue without damaging carbon nanotubes. They show that their stability is improved thanks to the presence of chlorine-containing functional groups at the carbon nanotube surface. Under the used conditions, the functionalization level remains low preserving the single-walled carbon nanotube (SWCNT) structure and efficiently protects SWCNTs from combustion by oxygen.

15/00019 Influences of heating rate during coal char preparation and AAEMs on volatile-char interaction with different sources of biomass volatile

Krerkkaiwan, S. *et al. Fuel Processing Technology*, 2014, 119, 10–18.

Volatile-char interaction is important for the operation of co-gasification of coal and biomass. Biomass generally produces large amount of volatiles while char is mainly produced from coal. Hence, in

this study, the interaction between coal char and volatiles from biomass samples (xylan, cellulose and rice straw) was examined using a rapid-heating thermobalance reactor. Three types of coal char, consisting of slow pyrolysed-coal char (Ex-char), fast pyrolysed-coal char (In-char), and acid washed-coal char (Ac-char), were employed to reveal influences of heating rate during char preparation and retention of alkali and alkaline earth metallic (AAEM) species on char surface. The steam gasification rates of all coal chars in both cases with and without volatile contacting were investigated from the gas evolution rate and remaining char analyses. The results indicate that the steam gasification rates of Ex-char and In-char were significantly diminished by the volatiles derived from all sources, especially rice straw. However, in the case of Ac-char, the reduction of steam gasification rate was less important. Moreover, the Ex-char exhibited the catalyst for the decomposition of biomass volatiles, resulting in the increase in gas production rate. Porous structure and the AAEM over char play crucial roles on the volatile-char interaction.

15/00020 Intrinsic reaction kinetics of coal char combustion by direct measurement of ignition temperature

Kim, R.-G. and Jeon, C.-H. *Applied Thermal Engineering*, 2014, 63, (2), 565–576.

A wire heating reactor that can use a synchronized experimental method was developed to obtain the intrinsic kinetics of large coal char particles ranging in size from 0.4 to 1 mm. This synchronization system consists of three parts: a thermocouple wire for both heating and direct measurement of the particle temperature, a photodetector sensor for determining ignition/burnout points by measuring the intensity of luminous emission from burning particles, and a high-speed camera-long-distance microscope for observing and recording the movement of luminous zone directly. Coal char ignition was found to begin at a spot on the particle's external surface and then moved across the entire particle. Moreover, the ignition point determined according to the minimum of dT/dt is a spot point and not a full growth point. The ignition temperature of the spot point rises as the particle diameter increases. A spot ignition model, which describes the ignition in terms of the internal conduction and external/internal oxygen diffusion, was then developed to evaluate the intrinsic kinetics and predict the ignition temperature of the coal char. Internal conduction was found to be important in large coal char particles because its effect becomes greater than that of oxygen diffusion as the particle diameter increases. In addition, the intrinsic kinetics of coal char obtained from the spot ignition model for two types of coal does not differ significantly from the results of previous investigators.

15/00021 Predicting the influence of ultrasonication energy on the reinforcing efficiency of carbon nanotubes

Chen, S. J. *et al. Carbon*, 2014, 77, 1–10.

Ultrasonication is extensively used in the fabrication of carbon nanotube (CNT) reinforced composites. However, there has been very limited research into predicting the effect of ultrasonication treatment on the reinforcing efficiency of CNTs. In this study, a theoretical framework with supporting experiments is developed to address this issue. The distribution of CNT lengths and the concentration of dispersed CNTs are characterized using scanning electron microscopy images and UV-vis spectra. After ultrasonication, the length of CNT is found to follow log-normal distributions which show a shortening effect. The concentration of dispersed CNT increases with ultrasonication energy but reaches a plateau after about 250 J/ml. The distribution of CNT lengths and the concentration of dispersed CNTs are incorporated into a micromechanics-based model to simulate the crack bridging behaviour of CNTs. Results show that the distribution of CNT lengths leads to better estimation of reinforcing effect than does the average length. Furthermore, for unit volume of dispersed CNTs, the reinforcing efficiency decreases monotonically with increased ultrasonication. Based on the proposed model, the predicted optimal ultrasonication energy (89 J/ml) for reinforcing is found before the dispersion plateau is reached.

15/00022 Study of briquetted biomass co-firing mode in power plants

Liu, Y. *et al. Applied Thermal Engineering*, 2014, 63, (1), 266–271.

A briquetted biomass co-firing mode that is feasible in China and other areas with dispersedly distributed biomass resources was proposed, and the details and characteristics of this mode are discussed. Raw biomass from sources such as corn stalks, twigs, and straws was crushed in farmlands and then transported to briquetting stations. The crushed biomass was dried and compressed into briquettes until the moisture content was less than 25%. Finally, the biomass briquettes were stored and delivered to plants like coals for combustion. One of the six layers of the pulverizing system in a 300 MW power plant could be used, and 100% biomass briquettes could be ground by an existing MPS medium-speed pulverizer. The biomass briquettes could then be delivered directly into the furnace by primary air. No additional equipment investments were needed for the plant because almost all equipment

was already available. Advantages such as cost-effective on biomass collection and transportation, high efficiency and low cost on biomass preprocessing, biomass briquette economic grinding and feeding, and efficient and clean combustion could be realized by this method. The economic sustainability of this mode was also analysed.

02 LIQUID FUELS

Sources, properties, recovery

15/00023 A modified MMM EOS for high-pressure PVT calculations of heavy hydrocarbons

Mohsen-Nia, M. *Journal of Petroleum Science and Engineering*, 2014, 113, 97–103.

A theoretical based cubic equation of state has been proposed (MMM EOS) by Mohsen-Nia for calculation of pure fluid and mixture properties $Z = (v + 1.3191b)/(v - b) - a/[RT^{1.5}(v + b)]$. In previous works, the superiority of the MMM has been shown over the vdW family of EOSs for PVT and VLE calculations. In this work, a new simple functional form for its attractive and repulsive parameters $a(T)$ and $b(T)$ is introduced. The proposed EOS is applied to vapour pressure and saturated density calculations of different pure fluids. Then, the proposed equation is used to calculate high-pressure PVT of heavy hydrocarbons. The performance of the proposed EOS for VLE calculations is examined against the corresponding experimental measurements for a number of binary mixtures and the results are compared with those obtained from the cubic EOSs frequently used for thermodynamic and fluid phase equilibrium calculations. The comparisons indicate the modified MMM EOS is quite suitable for property predictions of gas and liquid systems, especially for high-pressure PVT of heavy hydrocarbon systems of interest in the oil and gas industries.

15/00024 Antenna array design for enhanced oil recovery under oil reservoir constraints with experimental validation

Abdulrahman, M. M. and Meribout, M. *Energy*, 2014, 66, 868–880.

In this paper, a detailed mathematical model of electromagnetic (EM) heating for enhanced oil recovery (EOR) is presented. The model takes into consideration three different designs of the array of EM sources under the constraint of the dimensions, dielectric constituents, and geophysics properties of oil reservoirs. This includes a simple waveguide antenna, an E-plane spectral horn antenna of different dimensions and an array of waveguide antennas with and without deflected phases. Simulation studies have been performed at frequencies of 915, 2450 and 5800 MHz for the three aforementioned designs under different combinations of the placement, positioning and orientation of antennas. Furthermore, an experimental verification of the suggested model is addressed by designing and building a new experimental setup which has the advantage of being able to mimic more realistically real oil reservoirs as compared to microwave ovens. These were mainly used as the test platform by other researchers and feature substantial differences with oil field reservoirs. The corresponding results indicate a good matching (i.e. 95% matching) with the suggested model, while outperforming other traditional enhanced oil recovery techniques. This leads to state that EM-based EOR can be a good alternative to the other existing techniques.

15/00025 Effect of Marangoni flow on recovery of bypassed oil during CO₂ injection

Khosravi, M. *et al. Journal of Petroleum Science and Engineering*, 2014, 114, 91–98.

The authors have experimentally investigated the effect of interfacial tension gradient induced convective fluxes – Marangoni flow – on the recovery of bypassed oil during near-miscible and immiscible CO₂ injection in a 1D-matrix/fracture model. Hydrocarbon systems of components were designed such that the existence of Marangoni flow and its direction with respect to fracture could be managed. The results show reasonable agreement between recovery changes and Marangoni number, indicating the significant impact of Marangoni flow on the recovery of bypassed oil in porous media under high-pressure high-temperature conditions. The results of the experiments introduce the so-far neglected Marangoni phenomenon as a considerable mechanism of oil recovery in near-critical conditions.

15/00026 Lubricity assessment of gasoline fuels

Arkoudeas, P. *et al. Fuel Processing Technology*, 2014, 122, 107–119.

This paper presents the lubricity measurements of the three commercial gasoline types, unleaded gasoline (95 RON), new super or lead-replacement petrol (96 RON) and super unleaded gasoline (98 RON) and the effects of various physicochemical properties on lubricity. The results indicate that the nature of the fuel is an important factor for the lubrication properties of each type of gasoline fuel. The potassium content takes an active part in this and the amount that is added to the fuel doesn't seem to affect the final result of CWSI.1.4 proportionally. A careful statistical approach to the data identified that, the composition, the sulfur and nitrogen contents, the oxygen content that is mainly contributed from the methyl tert-butyl ether (MTBE) content and the viscosity, do affect the lubricity but in a different degree for each type of fuel. This differentiation of the properties' effect on lubricity, reinforces the idea of the complicated wear mechanism that takes place under the specific conditions of the experiments and the important role of the compositional characteristics of the fuel. Oxygen content and MTBE seem to maintain or even increase the wear mechanism. Chlorine was also detected on the metal surface of the specimens after scanning with electron microscopy.

15/00027 On in situ hydrogen sulfide evolution and catalytic scavenging in steam-based oil sands recovery processes

Kapadia, P. R. *et al. Energy*, 2014, 64, 1035–1043.

In the steam-assisted gravity drainage (SAGD) process, high temperature saturated-steam is injected into an oil sands reservoir to lower the viscosity of the bitumen hosted within the reservoir. Typical steam temperatures range from 200 to 260 °C. Under these conditions, the bitumen, in presence of steam-condensate, undergoes aquathermolysis yielding H_2S and CO_2 . Current SAGD simulation models take into account complex spatial heterogeneity of geology and oil composition and the physics of heat transfer, multiphase flow, gas solubility effects, and viscosity variations with temperature; however, few have taken the chemistry of SAGD into account. Here, aquathermolysis reactions were added to a simulation model to understand H_2S reactive zones in SAGD. Given the requirement to constrain sulfur emissions from thermal recovery processes, it is necessary to reduce H_2S production to surface. The results demonstrate that injecting small amount of SO_2 , along with steam, initiates the Claus reaction in the reservoir which converts H_2S into liquid sulfur. Thus, sulfur emissions are reduced below that of the original operation without SO_2 co-injection. The ability to use *in situ* Claus reaction-based H_2S scavenging offers an elegant way to reduce sulfur emissions from thermal oil sands recovery processes.

15/00028 Study on the formation, determination, and removal of elemental sulfur in ultra-low sulfur gas oil

Yin, C. *et al. Fuel Processing Technology*, 2014, 120, 16–21.

The question as to the formation of elemental sulfur in petroleum has never been definitely settled, although there are many references in the literature to the presence of elemental sulfur in distillates. In connection with studies on sulfur compounds in petroleum distillates, the presence and behaviour of elemental sulfur in gas oil, especially in ultra-low sulfur gas oil are important. A rapid and accurate method for the analysis of elemental sulfur by gas chromatography-pulsed flame photometric detector was developed and a series of experiments was carried out to clarify the formation mechanism of elemental sulfur. The results showed that $(NH_4)_2S_n$ was found to be easily oxidized to free sulfur when contacted with air and the oxidation of ammonium polysulfide was the main formation mechanism of elemental sulfur in the hydrotreating of gas oil. It was revealed that nitrogen-containing molecules in the oil feed and NH_4^+ contained in the hydrosulfurization catalyst can result in the formation of $(NH_4)_2S_n$. A method with high efficiency and selectivity to remove elemental sulfur from hydro-treated gas oil by Na_2S washing was developed for analysis purpose.

15/00029 The oxidation of heavy oil: thermogravimetric analysis and non-isothermal kinetics using the distributed activation energy model

Fan, C. *et al. Fuel Processing Technology*, 2014, 119, 146–150.

The oxidation behaviour and kinetics parameters of heavy oil oxidation are highly required to understand the reactivity of crude oil and gain novel recovery routes. In this contribution, thermogravimetric analysis was employed to investigate the oxidation behaviours of one typical kind of Chinese heavy oil, and the distributed activation energy model (DAEM) was applied to obtain accurate kinetic parameters of oxidation reactions from 30 to 550 °C and to bring new insights on the complex reactions and mechanistic understanding. The three stage oxidation – low-temperature oxidation (200–320 °C), plateau section (320–350 °C), and high-temperature oxidation (>350 °C) – was observed in the non-isothermal oxidation experiments. E vs V/V^* curve of whole oil oxidation follows similar pattern to the thermogravimetric profile. Thus, low-temperature oxidation and high-temperature oxidation are regarded as two character zones of heavy oil oxidation. The apparent activation energies at low temperatures are around 100 kJ/

mol, and at high temperatures are about 190–230 kJ/mol. The curves predicted from kinetic parameters afford a good approach with the experimental data demonstrating the reliability of the available kinetic parameters.

Transport, refining, quality, storage

15/00030 A CFD (computational fluid dynamic) simulation for oil leakage from damaged submarine pipeline

Zhu, H. *et al. Energy*, 2014, 64, 887–899.

The objective of the present paper is to study the oil flows from damaged submarine pipelines with different leak sizes. Computational fluid dynamic simulations with FLUENT software are carried out to investigate the process of oil spill from a submarine pipeline to the free surface. Effects of oil density, oil leaking rate, leak size and water velocity on the oil spill process are examined. High density, slow leaking, small leak size or fast current brings about an increased time for the oil to reach the maximum horizontal migration distance when it reaches the surface. And this maximum horizontal migration distance increases with the increase of leak size or water velocity, while increases with the decrease of leaking rate. Then, the dimensionless time required for oil droplets which have the longest horizontal migration distance when they reach the sea surface and the dimensionless longest horizontal distance the droplets migrate when they reach the sea surface are analysed and the fitting formulas are obtained. Only the formula for the dimensionless longest horizontal distance versus dimensionless density meets the polynomial, other five formulas meet the natural logarithm distribution. Using the formulas, the authors can obtain when and where to see oil reaching the sea surface, and conduct rapid response. Finally, the maximum horizontal migration distance of oil at certain time is predicted, and a forecasting model is proposed. The using methods of fitting formulas and the forecasting model are shown in the paper by examples. These calculated results provide useful guidance to place the oil containment boom.

15/00031 Biological souring of crude oil under anaerobic conditions

Tanji, Y. *et al. Biochemical Engineering Journal*, 2014, 90, 114–120.

Seawater injection into oil reservoirs for purposes of secondary oil recovery is frequently accompanied by souring (increased sulfide concentrations). Production of hydrogen sulfide causes various problems, such as microbiologically influenced corrosion (MIC) and deterioration of crude oil. Sulfate-reducing bacteria (SRB) are considered to be major players in souring. Volatile fatty acids (VFAs) in oil-field water are believed to be produced by microbial degradation of crude oil. The objective of this research was to investigate mechanisms of souring, focusing specifically on VFA production via crude oil biodegradation. To this end, a microbial consortium collected from an oil-water separator was suspended in seawater; crude oil or liquid n-alkane mixture was added to the culture medium as the sole carbon source, and the culture was incubated under anaerobic conditions for 190 days. Physicochemical analysis showed that preferential toluene degradation and sulfate reduction occurred concomitantly in the culture containing crude oil. Sulfide concentrations were much lower in the alkane-supplemented culture than in the crude oil-supplemented culture. These observations suggest that SRB are related to the toluene activation and VFA consumption steps of crude oil degradation. Therefore, the electron donors for SRB are not only VFA, but many components of crude oil, especially toluene. Alkanes were also degraded by microorganisms, but did not contribute to reservoir souring.

15/00032 Effect of retorting temperature on product yield and characteristics of non-condensable gases and shale oil obtained by retorting Huadian oil shales

Wang, S. *et al. Fuel Processing Technology*, 2014, 121, 9–15.

Oil shale samples from Huadian were retorted in a stainless-steel cylindrical retort under argon atmosphere to determine retorting temperature effect on the product yield and characteristics of shale oil and non-condensable gases produced. Increasing temperature from 430 to 520 °C improved both oil and gas yields, but reduced the oil/gas yield ratio. Raising temperature increased nitrogen content in the derived shale oil and decreased the atomic H/C ratio and oxygen content, but had no significant effect on the sulfur content. It was also noticed that the boiling point of shale oil generated at 490 °C was lowest, and the shale oils obtained at 430 and 460 °C showed similar boiling point distributions. The produced shale oils had similar atomic H/C ratio as well as higher light oil content compared to crude oils produced in China, and could be classified as sweet and high-nitrogen oil in terms of the classification method of crude oil. The oil derived at 490 °C contained the lowest amount of saturates and the highest amount of aromatics, asphaltenes and non-hydrocarbons. $C_{1-}C_4$

hydrocarbon gas contents rose with increasing temperature. Higher ethene/ethane, propene/propane, butene/butane and alkene/alkane ratios obtained at higher temperature were linked to secondary cracking reactions.

15/00033 Estimating the likelihood of pipeline failure in CO₂ transmission pipelines: new insights on risks of carbon capture and storage

Duncan, I. J. and Wang, H. *International Journal of Greenhouse Gas Control*, 2014, 21, 49–60.

Previous studies of risks associated with CO₂ pipelines for future carbon capture and storage (CCS) activities have used either the frequency of incidents associated with existing CO₂ pipelines or from natural gas pipelines as a proxy. Risks of CO₂ pipeline failure have been estimated as in the range of 1.2×10^{-4} to 6.1×10^{-4} km⁻¹ yr. This paper demonstrates that for US natural gas pipeline data, incident/failure metrics are not correlated with fatality rates. Both CO₂ and natural gas pipelines are fabricated from the same grades of carbon steel, and both are installed using the same equipment and practices. However, natural gas is lighter than air and explosive in air, whereas CO₂ is non-flammable but toxic (and heavier than air). Their risk profiles are therefore not identical, and the differences in hazard certainly impact the nature of individual and societal risk. This study focuses on the likelihood of events that could result in fatalities or injuries. The average fatality rate for natural gas transmission pipelines constructed over the past three decades is 1.0×10^{-6} km⁻¹ yr. This value can be viewed as an upper bound for estimating individual risks associated with CO₂ transmission pipelines. Use of incident rates to model individual risks for CO₂ pipelines, has overestimated these risks by two or three orders of magnitude. When pipelines are designed with factors of safety required by regulators for populated areas, analysis of natural gas pipeline data demonstrates that risks of significant accidental releases are extremely low. These results require a significant rethinking of previous notions of the risks associated with CO₂ pipelines.

15/00034 Internal and external HIDIcs (heat-integrated distillation columns) optimization by genetic algorithm

Shahandeh, H. *et al. Energy*, 2014, 64, 875–886.

A heat-integrated distillation column (HIDiC) is an effective energy-saving configuration especially for the separation of close boiling point mixtures. In this work, the stochastic methodology has been applied for optimization of both internal and external HIDiCs. The use of a genetic algorithm (GA) to find the optimal HIDiC configuration is presented while the fitness function is set to be the total annual cost (TAC). HIDiC simulation has been performed based on the modified MESH equations using a rigorous thermodynamic model. Introducing a novel integer variable (the layout number) leading to a more effective solution for the examined case study. This variable can generate systematically more energy efficient candidates for both internal and external HIDiCs. Benzene–toluene separation has been investigated by the proposed optimization procedure. The multivariable problem can be successfully optimized by a GA while a good initial estimation is not essential. Based on the final results, up to 6.60% and 9.75% TAC reduction have been accomplished in external and internal HIDiCs optimization using the proposed method compared to the reported solutions in a previous work for the examined case study. However, vapour recompression column optimization at the end of presented work results in 7.89% TAC reduction rather than optimal HIDiC.

15/00035 Mechanical behaviour of wellbore materials saturated in brine water with different salinity levels

Nasvi, M. C. M. *et al. Energy*, 2014, 66, 239–249.

In any carbon capture and sequestration (CCS) project, well cement plays a vital role as it provides the required zonal isolation and well integrity. Typical wellbore materials including well cement and formation rock will be exposed to a range of saturation mediums such as water and brine with different salinity levels. To date, ordinary Portland cement (OPC)-based well cement has been used. However, its survival has been questioned under CO₂ sequestration conditions, as it experiences cement degradation and strength reduction in saline water. Therefore, this experimental work investigates the mechanical characteristics of geopolymer (G) as well cement and sandstone (S) as formation materials. The mechanical behaviour of G, S and G–S composite materials in fresh water (W) and two concentrations of brine water (BW), 5% NaCl (5% BW) and 15% NaCl (15% BW), were studied. Based on the results, it was found that G, S and G–S samples experience strength reduction in W and BW. However, the reduction rate of G is almost half of that of OPC-based oil well cement. In addition, the strength reduction rates of G and G–S were less in 15% BW compared to W and 5% BW, due to the lower alkali leaching rates from G in BW compared to W. Therefore, saline aquifers with high NaCl content are always favourable for G well cement. The S samples showed constant strength reduction regardless of the saturation medium, and hence NaCl does not show any significant effect on the

mechanical behaviour of quartz-rich sandstone. The crack propagation stress thresholds were higher for G and G–S saturated in 15% BW compared to 5% BW. The S samples did not show major variation in crack propagation stress thresholds in W and BW. The ARAMIS strain measurement results showed that the maximum strain that wellbore materials experience at failure reduces with the introduction of brine. In addition, G and G–S undergo splitting failure, whereas S experiences shear failure in W and BW.

15/00036 Numerical study of choked two-phase flow of hydrocarbons fluids through orifices

Giacchetta, G. *et al. Journal of Loss Prevention in the Process Industries*, 2014, 27, 13–20.

Valves and orifices are the most widely devices of flow control used in oil and gas industry. In particular, they are installed in relief piping system in order to control the discharge flow during potential plant overpressuring scenarios, thus ensuring plant safety. It is a common practice to flow liquid and gas mixtures through such restriction devices. Rigorous models are available to precisely size pressure relief devices operating in single phase flow; however for two-phase flow, no models are considered sufficiently reliable for predicting the relevant flow conditions. In this paper, two-phase flow of hydrocarbons fluids through an orifice under critical conditions has been numerically investigated. The existing literature has been analysed and data on two-phase flow of highly volatile mixtures of hydrocarbons through openings have been collected. A comparison has been carried out with numerical simulations carried out by the multiphase flow simulation tool OLGA by SPT. The Henry–Fauske model has been used as orifice choke model and the orifice discharge flow coefficient, required as input by OLGA, has been calculated by Chisholm's model. Comparison between OLGA's results and experimental data shows that Henry–Fauske model markedly underestimates the mass flow rate through the orifice, if Chisholm's model is used to calculate discharge coefficient. It was found that the error of the model could be minimized using different values of orifice discharge coefficient (C_d). A new discharge flow coefficient model, suitable for choked two-phase flow across orifices, is proposed in this study and it has been determined to match the above mentioned experimental measurements.

15/00037 Prediction of the collapse pressure for thick-walled pipes under external pressure

He, T. *et al. Applied Ocean Research*, 2014, 47, 199–203.

Collapse behaviour of offshore pipelines under external pressure is a primary concern for ultimate limit state design criteria of structural integrity. In this work, finite element analyses of the collapse behaviour for long, moderately thick-walled steel pipes under external hydrostatic pressure were performed. The effects of initial ovality, yield stress and yield anisotropy on the collapse pressure were investigated. Besides, 441 finite element models of thick-walled pipes with practical configurations were constructed and analysed using Python (the programming language within the finite element software package ABAQUS). A simplified equation for predicting the critical plastic collapse pressure was given and recommended for calculating the pressure capacity of thick-walled pipes. The accuracy of the simplified equation was verified by the experimental results from other researchers.

15/00038 Ultra-deep adsorptive desulfurization of a model diesel fuel on regenerable Ni–Cu/γ-Al₂O₃ at low temperatures in absence of hydrogen

Mansouri, A. *et al. Journal of Hazardous Materials*, 2014, 271, 120–130.

A model diesel fuel containing 250 ppmw sulfur (as dibenzothiophene) in *n*-hexadecane was desulfurized at low temperatures in absence of hydrogen, down to about zero ppmwS on a novel adsorbent of well dispersed 3–12 nm Ni_x–Cu_{10–x} ($x = \text{Ni wt\%}$) nanoparticles formed by impregnation on γ-Al₂O₃ and reduced in H₂ at 275 or 450 °C. The sorbents were characterized by XRD, TEM–EDX, FESEM–EDS, H₂–TPR, TPO, BJH and BET surface area measurement techniques. Effects of various parameters comprising Cu content, reduction and desulfurization temperatures, inhibition by naphthalene, and regeneration of spent sorbents were investigated. As copper is added to nickel: (a) the sorbent reduction temperature shifts to dramatically lower values, (b) sulfur adsorption capacity of the sorbents at lower reduction and desulfurization temperatures is significantly improved, and when 14 wt% Ni₅Cu₅ sorbent is added to the fuel, the sulfur content reduces from 250 ppmwS to about zero in less than 1 min, (c) loss of adsorption capacity after the regeneration of the spent sorbent reduced at 275 °C is significantly diminished, and (d) the selectivity of the sorbents to dibenzothiophene in the presence of naphthalene is improved. A higher reduction temperature tends to agglomerate nickel nanoparticles and reduce the sulfur adsorption capacity.

Economics, business, marketing, policy

15/00039 Amuay refinery disaster: the aftermaths and challenges ahead

Mishra, K. B. *et al. Fuel Processing Technology*, 2014, 119, 198–203.
The Amuay refinery disaster in 2012 in Venezuela is another recent example of vapour cloud explosion and fire accidents preceded by Buncefield (2005), Puerto Rico (2009) and Jaipur (2009), respectively. The incident has left many safety issues behind which must be repeatedly addressed. Unfortunately, the lessons taught by previous similar events are just not understood carefully. It reveals that the proper safety measures for such facilities were either underestimated or were not accounted seriously. Consequently, the resulting overpressures from explosion and the subsequent thermal radiation from tank fires have once again proved to be disastrous to both mankind and infrastructure. This article highlights the aftermaths of Amuay incident and addresses the challenges put forward by it. Furthermore, a comparative study is performed between such incidents to analyse the similarities and how they could have been avoided.

15/00040 An ethanol blend wall shift is prone to increase petroleum gasoline demand

Qiu, C. *et al. Energy Economics*, 2014, 44, 160–165.
In 2010, the US Environmental Protection Agency announced a waiver allowing an increase in the fuel–ethanol blend limit (the ‘blend wall’) from 10% (E10) to 15% (E15). Justifications for the waiver are reduced vehicle-fuel prices and less consumption of petroleum gasoline, leading to greater energy security. Empirical investigations of this waiver using Monte Carlo simulations reveal an anomaly where a relaxation of this blend wall elicits a demand response. Under a wide range of elasticities, this demand response can actually increase the consumption of petroleum gasoline and thus lead to greater energy insecurity. The economics supporting this result and associated policy implications are developed and discussed.

15/00041 Crude oil prices and exchange rates: causality, variance decomposition and impulse response

Brahmasrene, T. *et al. Energy Economics*, 2014, 44, 407–412.
This paper examines the short- and long-run dynamic relationship between the US imported crude oil prices and exchange rates. The monthly data of the US crude oil imports from five source countries during January 1996 and December 2009 are examined. Empirical results indicate that the exchange rates Granger-caused crude oil prices in the short run while the crude oil prices Granger-caused the exchange rates in the long run. Furthermore, oil prices were affected by the exchange rate changes at a minimal level. However, in the medium run and the long run, oil price shocks had a significant impact on exchange rate changes. Exchange rate shock has a significant negative impact on crude oil prices while the impulse response of the exchange rate variable to a crude oil price shock was statistically insignificant. Finally, the impact of extreme price volatility in June 2008 on exchange rates was significant. When world oil prices are stabilized, currency fluctuations and uncertainty can be minimized.

15/00042 Development and application of near-well multiphase upscaling for forecasting of heavy oil primary production

Li, H. *et al. Journal of Petroleum Science and Engineering*, 2014, 113, 81–96.
Near-well effects can have a strong impact on reservoir flow. Current reservoir modelling practice often uses coarse-scale flow simulation models, which may lead to biased results, compared with fine-scale models. This study extends and applies a recently developed near-well multiphase flow upscaling technique to the coarse-scale simulation of heavy-oil primary production. For heavy oils, oil viscosity is a strong function of pressure when the pressure is below the bubble point. Therefore, the upscaled mobility functions (from near-well multiphase upscaling) depend on both pressure and saturation, which cannot be directly input to general purpose reservoir simulators. This is very different than the upscaled mobility functions for typical black-oil fluids, in which oil viscosity does not vary significantly with pressure. Accordingly, the upscaled mobility functions are often equivalent to upscaled relative permeabilities (as functions of saturation only). Two procedures to derive either the upscaled relative permeability or viscosity functions from the phase mobility functions were developed, thus decoupling the dependency on pressure and saturation. It was found that the upscaled oil viscosity provides more accurate predictions than the upscaled relative permeabilities, especially at early time. This is because that the rapid change of pressure at the early stage of production is captured sufficiently in the upscaled oil viscosity (as a function of pressure). The use of upscaled viscosity function in multiphase upscaling is new, and has not been presented in previous studies. A grouping technique was also introduced to reduce the

number of upscaled flow functions in coarse-scale models. This was based on an observation that there is a strong correlation between the upscaled flow functions and the coarse-scale well-block permeabilities. The proposed methods were applied to realistic models from heavy-oil fields. For the cases considered, the near-well multiphase flow upscaling considerably improved upon the standard coarse-scale models. The use of upscaled relative permeability and viscosity functions, as well as the grouping of upscaled flow functions, provided practical applicability of the proposed method.

15/00043 Dynamic spillovers of oil price shocks and economic policy uncertainty

Antonakakis, N. *et al. Energy Economics*, 2014, 44, 433–447.
This study examines the dynamic relationship between changes in oil prices and the economic policy uncertainty index for a sample of both net oil-exporting and net oil-importing countries over the period January 1997 to June 2013. To achieve that, an extension of the dynamic spillover index based on structural decomposition is employed. The results reveal that economic policy uncertainty (oil price shocks) responds negatively to aggregate demand oil price shocks (economic policy uncertainty shocks). Furthermore, during the recession of 2007–2009, total spillovers increase considerably, reaching unprecedented heights. Moreover, in net terms, economic policy uncertainty becomes the dominant transmitter of shocks between 1997 and 2009, while in the post-2009 period there is a significant role for supply-side and oil specific demand shocks, as net transmitters of spillover effects. These results are important for policy makers, as well as, investors interested in the oil market.

15/00044 Evaluation and update of Norwegian and Danish oil production forecasts and implications for Swedish oil import

Sällh, D. *et al. Energy*, 2014, 65, 333–345.
This paper presents an updated historic oil production analysis as well as an updated future oil production forecast for Norway and Denmark. Previous forecasts conducted by academic and official agencies using a variety of methodologies are contrasted and their accuracy examined. The bottom-up field-by-field methodology is found to be precise in the short term, as it deviates by less than 1% from actual production. The impact of declining oil production in the North Sea on Sweden is explored as a case study. The historic and future trends regarding Swedish oil imports are presented and their vulnerability assessed using the Herfindahl–Hirschman index.

15/00045 Forecasting the limits to the availability and diversity of global conventional oil supply: validation

Hallock Jr., J. L. *et al. Energy*, 2014, 64, 130–153.
Oil and related products continue to be prime enablers of the maintenance and growth of nearly all of the world's economies. The dramatic increase in the price of oil through mid-2008, along with the coincident (and possibly resultant) global recession, highlight the continued vulnerability to future limitations in the supply of cheap oil. The very large differences between the various estimates of the original volume of extractable conventional oil present on earth (extractable ultimate resource, EUR) have, at best, fostered uncertainty of the risk of future supply limitations among planners and policy makers, and at worse lulled the world into a false sense of security. In 2002, the future oil production was modelled in 46 nation-units and the world by using a three-phase, Hubbert-based approach that produced trajectories dependent on settings for EUR, demand growth, percentage of oil resource extracted at decline, and maximum allowable rates of production growth. The authors analysed the sensitivity of the date of onset of decline for oil production to changes in each of these input parameters. This study compares the last 11 years of empirical oil production data to the earlier forecast scenarios to evaluate which settings of EUR and other input parameters had created the most accurate projections. When combined with proper input settings, the model consistently generated trajectories for oil production that closely approximated the empirical data at both the national and the global level. In general, the lowest EUR scenarios were the most consistent with the empirical data at the global level and for most countries, while scenarios based on the mid and high EUR estimates overestimated production rates by wide margins globally. The global production of conventional oil began to decline in 2005, and has followed a path over the last 11 years very close to the scenarios assuming low estimates of EUR (1.9Gbbbl). Production in most nations is declining, with historical profiles generally consistent with Hubbert's premises. While new conventional oil discoveries and production starts are expected in the near term, the magnitudes necessary to increase the simulated production trajectories by even 1.0% per year over the next 10 years would represent a large departure from current trends. The now well-validated simulations are at significant variance from many recent ‘predictions’ of extensive future availability of conventional oil.

15/00046 Investment and production costs of synthetic fuels – a literature survey

Haarlemmer, G. *et al. Energy*, 2014, 66, 667–676.

Synthetic fuels, or synfuels, can be produced from gas, coal and biomass. The conversion of gas and coal is well established but lignocellulosic biomass conversion is slow to develop. This paper addresses the issue of the production cost of second generation biofuels via the thermo-chemical route, biomass to liquids (BtL). Techno-economic studies help identify promising conversion processes, but also introduce a false confidence in the technology that may lead to ill-fated decisions. A large number of techno-economic studies have been published since 2000 showing a large variability in the results. This paper analyses the published data and presents causes of the observed variability, including a comparison with coal and gas to liquids. Large uncertainties remain however with regard to the precision of the economic predictions. It will be shown that the spread in the economic source data accounts for much of the spread in the predictions. These uncertainties affect both coal-to-liquid and BtL cost predictions. It will be shown however that the results are relatively coherent and that most of the differences between the costs of synthetic fuels can be traced back to economies of scale considering mature technology.

15/00047 Oil price shocks and agricultural commodity prices

Wang, Y. *et al. Energy Economics*, 2014, 44, 22–35.

While the impacts of oil price changes on agricultural commodity markets are of great interest to economists, previous studies do not differentiate oil-specific shocks from aggregate demand shocks. This study addresses this issue using a structural VAR analysis. The findings indicate that the responses of agricultural commodity prices to oil price changes depend greatly on whether they are caused by oil supply shocks, aggregate demand shocks or other oil-specific shocks mainly driven by precautionary demand. Oil shocks can explain a minor fraction of agricultural commodity price variations before the food crisis in 2006–2008, whereas in post-crisis period their explanatory abilities become much higher. After crisis, the contributions of oil-specific factors to variations in agricultural commodity prices are greater than those of aggregate demand shocks. The results from an alternative SVAR confirm the robustness of the main findings.

15/00048 Optimal gasoline tax in developing, oil-producing countries: the case of Mexico

Antón-Sarabia, A. and Hernández-Trillo, F. *Energy Policy*, 2014, 67, 564–571.

This paper uses Parry and Small's methodology to estimate the optimal gasoline tax for a less-developed oil-producing country. The relevance of the estimation relies on the differences between less-developed countries (LDCs) and industrial countries. The authors argue that lawless roads, general subsidies on gasoline, poor mass transportation systems, older vehicle fleets and unregulated city growth make the tax rates in LDCs differ substantially from the rates in the developed world. It was found that the optimal gasoline tax is \$1.90 per gallon at 2011 prices and show that the estimate differences are in line with the factors hypothesized. In contrast to the existing literature on industrial countries, this study shows that the relative gasoline tax incidence may be progressive in Mexico and, more generally, in LDCs.

15/00049 Quantifying China's oil import risks and the impact on the national economy

Sun, M. *et al. Energy Policy*, 2014, 67, 605–611.

With an increase in China's oil imports, China's oil supply will also continue to be affected by the socio-economic stability of oil-exporting countries and the safety of oil transport routes. This paper introduces a systematic and quantitative method to evaluate the influence of China's oil import risks (OIR) on the national economy and industrial sectors from a perspective of supply chain process. For this analysis, China's OIR is quantified by integrating oil exporting country risk and the risks from oil transportation routes. Country risk is defined as the oil-exporting country's political risk caused by political changes or internal conflicts. Transport risk is defined as the risk of shipping routes affected by pirate attacks and geopolitics. Second, the relationship between China's OIR and oil import costs is analysed using a multiple linear approach. Third, an input-output analysis method is used to research the effect of the cost of China's oil imports on the cost of investment within China's domestic sectors. This research finds that the corresponding impact on gross domestic product is US\$3494.5 million given an increasing by 10% of China's OIR. And the impact on domestic sectors differs from sector to sector. Finally, this paper puts forth recommendations to improve long-term oil supply security in China.

15/00050 The dynamics of oil consumption and economic growth in Malaysia

Park, S.-Y. and Yoo, S.-H. *Energy Policy*, 2014, 66, 218–223.

This study attempts to investigate the causal relationship between oil consumption and economic growth in Malaysia where oil consumption and real gross domestic product have rapidly increased in recent years. To this end, the study employs annual data covering the period 1965–2011. Tests for unit roots, co-integration, and Granger-causality based on the error-correction models are presented. The overall results support the existence of bi-directional causality between oil consumption and economic growth in Malaysia. This means that an increase in oil consumption directly affects economic growth. Thus, in order not to make an adverse effect on economic growth, Malaysia should endeavour to overcome the constraints on oil consumption. Moreover, it appears that economic growth induces oil consumption.

15/00051 The impact of global oil price shocks on China's bulk commodity markets and fundamental industries

Zhang, C. and Chen, X. *Energy Policy*, 2014, 66, 32–41.

This paper investigated the reaction of aggregate commodity market to oil price shocks and also explored the effects of oil price shocks on China's fundamental industries: metals, petrochemicals, grains and oilseeds. The authors separated the volatilities of oil price into expected, unexpected and negatively expected categories to identify how oil prices influence bulk commodity markets. They contrasted the results between different periods and among classified indices, in order to discover the significant changes in recent years and the differences at an industry level. The results indicate that the aggregate commodity market was affected by both expected and unexpected oil price volatilities in China. The impact of unexpected oil price volatilities became more complex after 2007. The metals and grains indices did not significantly respond to the expected volatility in oil prices, in contrast to the petrochemicals and oilseeds indices. These results not only contribute to advancing the existing literature, but also merit particular attention from policy makers and market investors in China.

15/00052 The influence of South Korean energy policy on OPEC oil exports

Almansoori, A. *Energy Policy*, 2014, 67, 572–582.

South Korea is the fifth top oil importer worldwide with 64% of its oil coming from OPEC member countries. Over the past 30 years, South Korea accounted for a rapid increase in energy use. This in turn led South Korea to be totally dependent on oil imports. Due to this increase, South Korea has been experiencing drastic changes in its energy system which could potentially impact its dependence on OPEC oil import. External and internal factors have forced South Korea to change its energy strategy and targets. These targets would be achieved by reducing its energy intensity and utilizing electricity and renewable energies in order to reduce its dependence on oil consumption. 'Low Carbon, Green Growth' is one policy along with many other energy policies developed by South Korea for reducing greenhouse gases, thus this policy is receiving a remarkable attention today. These national policies along with other international ones are needed to mitigate greenhouse gas emissions and promote other green initiatives. This study puts emphasis on these policies as well as uses them to predict the future energy profile of South Korea and how these policies will impact on oil imports from OPEC member countries.

15/00053 Thermoeconomic and environmental assessment of a crude oil distillation unit of a Nigerian refinery

Waheed, M. A. *et al. Applied Thermal Engineering*, 2014, 66, (1–2), 191–205.

The renovation of refineries should be aimed at achieving the highest possible technical efficiencies at a considerable investment cost and not only at replacing damaged components to attain full capacity utilization. This study examined a crude distillation unit (CDU) of a Nigerian refinery plant comprising the atmospheric distillation unit (ADU), vacuum distillation unit (VDU), preflash unit (PFU), splitter unit (SPU), stabilizer unit (SBU) and heat exchanger network (HEN) to determine critical areas of inefficiencies as the plant managements plan renovation. Using real plant data, the CDU was simulated with Aspen Hysys and the thermoeconomic and environmental analyses were carried out. The results show that the energy and exergy efficiencies of the CDU were 9.0 and 4.0%, respectively. The specific CO₂ emission was 3.67 kg CO₂/bbl. The highly inefficient subunits accounting for 77.4 and 90.0% of the overall energy and exergy losses respectively and 60.3% of the emission released were the PFU, ADU and HEN. The highly inefficient components are the furnaces which accounted for 51.6% of the overall exergy losses. The environmental and economic analysis also indicated that these components are the most potent for improvement. The columns of the PFU and ADU should be revamped to reduce their energy demands and the HEN should be modified to minimize effluent losses.

Derived liquid fuels

15/00054 Coal water slurry using dispersant synthesized from cashew nut shell liquid (CNSL)

Phulkard, P. *et al. Fuel Processing Technology*, 2014, 119, 256–262.
The present work reports the preparation of coal–water slurry (CWS) containing cardanol–formaldehyde sulfonate (CFS) which was synthesized by sulfomethylation reaction of cardanol. It is found that the surface tension of CFS decreases with increasing concentration, indicating its good surface activity. Further, CWS (at 50 wt% coal) containing CFS in the concentration range of 1.0–1.8 wt% exhibits a marked decrease of viscosity which is similar to that of CWS containing sodium lignosulfonate (SL). In addition, the stability of CWS containing CFS of 1.0 wt% gives below 50% of penetration ratio for a period of as long as 1 month whereas less than 30% for CWS without dispersant. As a result, it demonstrates that CWS containing CFS of 1.0 wt% exhibits the properties within the specification similar to that of SL.

15/00055 Cobalt catalyst coated metallic foam and heat-exchanger type reactor for Fischer–Tropsch synthesis

Park, J. C. *et al. Fuel Processing Technology*, 2014, 119, 60–66.
A system consisting of a cobalt catalyst coated metallic foam and heat-exchanger type reactor was developed with the consideration of the severe heat and mass transfer limitations in the Fischer–Tropsch synthesis reaction. The system showed highly desirable results not only in terms of its low CH_4 and CO_2 selectivities, but also its high C_{5+} productivity, because of its enhanced heat and mass transfer properties in the reaction. The effects of the synthesis gas flow rate and reaction temperature on the CO conversion and C_{5+} productivity were also investigated. The CO conversion decreased, but the C_{5+} selectivity increased, with increasing synthesis gas flow rate, because the former was strongly affected by the reaction contact time and the latter was deeply related to the superficial velocity of the synthesis gas in the reactor. Furthermore, this system effectively prevented the formation of CH_4 , even at high temperature, and reduced the diffusional restrictions of the hydrocarbons produced in the catalyst pores with the temperature. The system of cobalt catalyst coated metallic foam and heat-exchanger type reactor resulted in a high C_{5+} productivity of 141.4 ml/kg_{cat} h at the high reaction temperature of 231 °C.

15/00056 Emissions from DME combustion in diesel engines and their implications on meeting future emission norms: a review

Thomas, G. *et al. Fuel Processing Technology*, 2014, 119, 286–304.
Dimethyl ether (DME) is an alternative liquid fuel developed mainly from coal and natural gas that can be used in compression ignition (CI) engines without major modifications to the diesel configuration. One of the advantages of DME combustion is the low emission levels of nitrous oxides (NO_x) and particulate matter (PM) when compared to diesel combustion. Research so far was largely focused on tackling issues due to less viscosity and low heating capacity of DME as compared to diesel and in developing DME specific fuel system to overcome its incompatibility with rubber seals. In this paper, the body of experimental and numerical research on gaseous and PM emissions from DME combustion is reviewed, with the objective being to identify promising methods for emission control in DME engines. Gaseous emissions from DME combustion is a well-researched topic, while PM emissions has not yet been explored in detail. PM emissions, especially ultra-fine particulate matter, are expected to become a major concern with the implementation of future emission norms. This review paper critically evaluates some of the novel methods of emission control in CI engines to meet future emission regulations using fuel injection strategies, combustion after-treatment and suggests future direction for DME research.

15/00057 Energy security analysis: the case of constrained oil supply for Ireland

Glynn, J. *et al. Energy Policy*, 2014, 66, 312–325.
Ireland imports 88% of its energy requirements. Oil makes up 59% of total final energy consumption (TFC). Import dependency, low fuel diversity and volatile prices leave Ireland vulnerable in terms of energy security. This work models energy security scenarios for Ireland using long-term macroeconomic forecasts to 2050, with oil production and price scenarios from the International Monetary Fund, within the Irish TIMES energy systems model. The analysis focuses on developing a least cost optimum energy system for Ireland under scenarios of constrained oil supply (0.8% annual import growth, and –2% annual import decline) and subsequent sustained long-term price shocks to oil and gas imports. The results point to gas becoming the dominant fuel source for Ireland, at 54% total final energy consumption in 2020, supplanting oil from reference projections of 57% to 10.8% TFC. In 2012, the cost of net oil imports stood at €3.6 billion (2.26% of gross domestic product). The modelled high oil and gas price scenarios show

an additional annual cost in comparison to a reference of between €2.9 billion and €7.5 billion by 2020 (1.9–4.9% of gross domestic product) to choose to develop a least cost energy system. Investment and ramifications for energy security are discussed.

15/00058 Exergy analysis for fuel reduction strategies in crude distillation unit

Nur Izyan, Z. and Shuhaimi, M. *Energy*, 2014, 66, 891–897.
Inefficient furnaces and heat exchangers contribute to the depletion of fossil fuel problem due to higher fuel demand and higher carbon emission. Exergy analysis is applied to the furnace and crude preheat train (CPT) in a crude distillation unit in order to determine performance benchmark of the system. This paper presents exergy analysis and strategies to reduce exergy loss through process modification. The highest exergy loss was found to be located at the inlet furnace. The proposed options for fuel reduction strategies are reduction of heat loss from furnace stack and overall cleaning schedule of CPT. The feasibility and economic analysis for both options are investigated. From the results, overall cleaning schedule of CPT contributes to the highest energy saving of 5.6%. However, reduction of heat loss from furnace stack is the highest cost saving by about 6.4%.

15/00059 Hydro-methane and methanol combined production from hydroelectricity and biomass: thermo-economic analysis in Paraguay

Rivarolo, M. *et al. Energy Conversion and Management*, 2014, 79, 74–84.

A thermo-economic analysis regarding large-scale hydro-methane and methanol production from renewable sources (biomass and renewable electricity) is performed. The study is carried out investigating hydrogen and oxygen generation by water electrolysis, mainly employing the hydraulic energy produced from the 14 GW Itaipu Binacional Plant, owned by Paraguay and Brazil. Oxygen is employed in biomass gasification to synthesize methanol; the significant amount of CO_2 separated in the process is mixed with hydrogen produced by electrolysis in chemical reactors to produce hydro-methane. Hydro-methane is employed to supply natural gas vehicles in Paraguay. Methanol is sold to Brazil – the largest consumer in South America. The analysis is performed employing time-dependent hydraulic energy related to the water that would normally not be used by the plant, named ‘spilled energy’, when available; in the remaining periods, electricity is acquired at higher cost by the national grid. For the different plant lay-outs, a thermo-economic analysis has been performed employing two different software, one for the design point and one for the time-dependent one entire year optimization, since spilled energy is strongly variable throughout the year. Optimal sizes for the generation plants have been determined, investigating the influence of electricity cost, size and plant configuration.

15/00060 Liquid oil and residual characteristics of printed circuit board recycle by pyrolysis

Lin, K.-H. and Chiang, H.-L. *Journal of Hazardous Materials*, 2014, 271, 258–265.

Non-metal fractions of waste printed circuit boards (PCBs) were thermally treated (200–500 °C) under nitrogen atmosphere. Carbon, hydrogen and nitrogen were determined by elemental analyser, bromine by instrumental neutron activation analysis, phosphorus by energy dispersive X-ray spectrometer and 29 trace elements by inductively coupled plasma (ICP) atomic emission spectrometer and ICP mass spectrometry for raw material and pyrolysis residues. Organic compositions of liquid oil were identified by gas chromatography–mass spectrometry, trace element composition by ICP system, and 12 water-soluble ions by ionic chromatography. Elemental content of carbon was >450 mg/g, oxygen 300 mg/g, bromine and hydrogen 60 mg/g, nitrogen 30 mg/g, and phosphorus 28 mg/g. Sulfur was trace in PCBs. Copper content was 25–28 mg/g, iron 1.3–1.7 mg/g, tin 0.8–1.0 mg/g and magnesium 0.4–1.0 mg/g; those were the main metals in the raw materials and pyrolytic residues. In the liquid products, carbon content was 68–73%, hydrogen was 10–14%, nitrogen was 4–5%, and sulfur was less than 0.05% at pyrolysis temperatures from 300 to 500 °C. Phenol, 3-bromophenol, 2-methylphenol and 4-propan-2-ylphenol were major species in liquid products, accounting for >50% of analysed organic species. Bromides, ammonium and phosphate were the main species in water sorption samples for PCB pyrolysis exhaust.

15/00061 Rheological behavior of coal bio-oil slurries

Feng, P. *et al. Energy*, 2014, 66, 744–749.
Coal bio-oil slurries (CBSs) were prepared by blending coal with bio-oil from the fast pyrolysis, and their apparent viscosities were measured by a rotary viscometer. The influences of coal rank, solid concentration, particle size distribution and temperature on the apparent viscosity and rheological properties of slurries were investigated. Additionally, the grey relational analysis was employed to determine the order of importance of factors affecting the apparent viscosity for different rank coals. Results show that, the CBS exhibits non-Newtonian fluid

behaviour and can be described by the Herschel–Bulkley equation. The main factors for different rank coals affecting apparent viscosity of CBS are inherent moisture and carboxyl groups. The maximum solid concentration of CBS can reach 45–47 wt% for Shenmu bituminous coal. Appropriate solid particle size distribution and preparation temperature can provide satisfied slurries with low viscosity.

15/00062 Saccharification behavior of cellulose acetate during enzymatic processing for microbial ethanol production

Hama, S. *et al. Bioresource Technology*, 2014, 157, 1–5.

This study was conducted to realize the potential application of cellulose acetate to enzymatic processing, followed by microbial ethanol fermentation. To eliminate the effect of steric hindrance of acetyl groups on the action of cellulase, cellulose acetate was subjected to deacetylation in the presence of 1 N sodium hydroxide and a mixture of methanol/acetone, yielding 88.8–98.6% at 5–20% substrate loadings during a 48 h saccharification at 50 °C. Ethanol fermentation using *Saccharomyces cerevisiae* attained a high yield of 92.3% from the initial glucose concentration of 44.2 g/L; however, a low saccharification yield was obtained at 35 °C, decreasing efficiency during simultaneous saccharification and fermentation (SSF). Presaccharification at 50 °C prior to SSF without increasing the total process time attained the ethanol titres of 19.8 g/L (5% substrate), 38.0 g/L (10% substrate), 55.9 g/L (15% substrate), and 70.9 g/L (20% substrate), which show a 12.0–16.2% improvement in ethanol yield.

03 GASEOUS FUELS

Sources, properties, recovery, treatment

15/00063 Block scale investigation on gas content of coalbed methane reservoirs in southern Qinshui basin with statistical model and visual map

Liu, H. *et al. Journal of Petroleum Science and Engineering*, 2014, 114, 1–14.

This study performs a block scale investigation on gas content of a coal reservoir in Zhengzhuang Block of the southern Qinshui basin in China. The gas content of coal seam No. 3 in this coal reservoir was measured in field and laboratory in conjunction with tests on coal properties such as adsorption isotherm, maximum vitrinite reflectance, coal composition and maceral component, etc. A total of 36 coal cores collected from three adjacent coalmines in the southern Qinshui basin were investigated, including analysis of logging data from the drilling wells. The investigations provided experimental data for block scale modelling and visualization analyses on the correlation between gas content and the key factors such as coal properties and geological conditions of the coal reservoir. Data obtained by field and lab tests were analysed by statistical models in order to correlate gas content and individual type of coal properties and geological variables. The statistical model was then used to map the gas content of the target coal seam in the studied area, resulting in a flood map of gas content at a 1:50,000 scale. The flood map was further visualized with other variables in terms of the properties of coal and coal reservoir and its geological conditions. These visualized maps provide useful geological interpretation for block scale investigation of the comprehensive relationships between the gas content and the coal properties and regional structure in the given coal reservoir. The results show that gas content has little correlation with coal rank, maceral composition, coal thickness, cap and bottom lithology, while it is highly related to the structural properties such as burial depth and effective cover thickness. A stagnant hydrodynamic condition is favourable to the higher gas content on the whole but does not contribute to gas lateral and local variation. Canonical correlation and principal component analysis on the statistical model reveal the key factors that control the gas content are burial depth, effective thickness of overlying strata, groundwater level and moisture content in coal seam.

15/00064 Deepwater gas kick simulation with consideration of the gas hydrate phase transition

Wang, Z.-y. and Sun, B.-j. *Journal of Hydrodynamics, Ser. B*, 2014, 26, (1), 94–103.

The hydrate phase transition presents new problems and challenges for the deepwater well control in the drilling processes. A simulation model is built for deepwater gas kicks with consideration of the hydrate

phase transition. The model is based on the multiphase flow governing equations and the hydrate phase transition calculation equations. The influence of the hydrate phase transition on the gas kick hydraulics is investigated through numerical simulations. It is shown that the diameter of the gas bubbles can significantly influence the hydrate phase transition effect. The influence of the hydrate phase transition on the gas kick hydraulics increases with the decrease of the average gas bubble diameter. The hydrate phase transition adds a 'hidden' nature for the well kick in deepwater and hinders the early detection of the gas kick. The influence of the hydrate phase transition on the gas kick hydraulics is also studied in the case when the hydrate inhibitor is added to the drilling fluid.

15/00065 Efficient estimation of natural gas compressibility factor using a rigorous method

Fayazi, A. *et al. Journal of Natural Gas Science and Engineering*, 2014, 16, 8–17.

The compressibility factor (Z-factor) of natural gases is necessary in many gas reservoir engineering calculations. Accurate determination of this parameter is of crucial need and challenges a large number of used simulators in petroleum engineering. Although numerous studies for prediction of gas compressibility factor have been reported in the literature, the accurate prediction of this parameter has been a topic of debate in the literature. For this purpose, a new soft computing approach namely, least square support vector machine (LSSVM) modelling optimized with coupled simulated annealing optimization technique is implemented. The model is developed and tested using a large database consisting of more than 2200 samples of sour and sweet gas compositions. The developed model can predict the natural gas compressibility factor as a function of the gas composition (mole percent of C₁–C₇₊, H₂S, CO₂, and N₂), molecular weight of the C₇₊, pressure and temperature. The calculated Z-factor values by developed intelligent model are also compared with predictions of other well-known empirical correlations. Statistical error analysis shows that the developed LSSVM model outperforms all existing predictive models with average absolute relative error of 0.19% and correlation coefficient of 0.999. Results from present study show that implementation of LSSVM can lead to more accurate and reliable estimation of natural gas compressibility factor.

15/00066 Experimental studies on stability and viscoplastic modeling of colloidal gas aphron (CGA) based drilling fluids

Arabloo, M. and Shahri, M. P. *Journal of Petroleum Science and Engineering*, 2014, 113, 8–22.

This paper presents results of bubble size distribution, stabilization, and statistical evaluation of rheological behaviour of drilling fluids containing colloidal gas aphrons (CGAs). The stability analysis of CGAs is investigated using drainage rate measurement, monitoring bubble growth rate and shear stress/shear rate measurement over time. Eight rheological models are also employed to make a quantitative description of the shear flow behaviour of CGA-based drilling fluids. The applicability of each model is examined in detail. Finally, a new model to combine the effects of temperature and shear rate on the viscosity of CGA-based drilling fluids is put forward. The results of this study can be helpful in selecting the appropriate procedure for utilizing the CGA-based drilling fluids in oilfield drilling operation.

15/00067 Selection of suitable aqueous potassium amino acid salts: CH₄ recovery in coal bed methane via CO₂ removal

Park, S. *et al. Fuel Processing Technology*, 2014, 120, 48–53.

This study identified suitable potassium amino acid salt absorbents for CO₂ removal for purposes of recovering CH₄ from coal bed methane (CBM). Critical concentrations of each blended solvent that did not produce any precipitate during CO₂ absorption were checked. From among these, eight solvents were selected that gave no precipitate. The selected absorbents were assessed in terms of their CO₂ loading capacity and absorption/desorption rate in comparison with mono-ethanolamine (MEA) through a screening test. A 10% CO₂ balance was regulated in CH₄, because the feed gas was assumed to approximate the CBM. From the results obtained, it seems that 4 M SAR, 1.5 M ALA + 1 M PZ, and 1.5 M SER + 1 M PZ are good CO₂ absorbents, because their cyclic CO₂ loading (0.223, 0.208 and 0.18 mol, respectively, of CO₂/mol of absorbent) is higher than those of other selected solvents (e.g. 4 M GLY + 1 M PZ, which has the lowest cyclic CO₂ loading). In addition, the authors checked that the high concentration of amino acid salts interrupted CO₂ absorption, decreasing the solubility. These solvents also have a relatively high surface tension at 25 °C (70.6; 73.3; 68.6 mN/m), when compared with pure water it (72.0 mN/m). It was therefore concluded that the suggested absorbent is adequate for use in the CO₂ removal process.

Transport, storage

15/00068 Effect of a gas charge explosion at the closed end of a gas storage system

Sochet, I. *et al. Journal of Loss Prevention in the Process Industries*, 2014, 27, 42–48.

This study proposed the analysis of an accidental detonation scenario in a gas storage warehouse and conducted experiments and numerical studies on a small scale. The performed study highlighted the field effects of strong overpressure generated by the detonation of an explosive charge located at the closed end of the warehouse in a corner. The analysis of the propagation shock wave inside the gas storage warehouse shows that maximal overpressure is independent of the presence of bottle crate. The measured and calculated values are in each case higher than in free field at same reduced distance, excepted for the gauge IG1 which gives an identical overpressure. The study on the effect of detonation of gas located at the closed end of the gas storage warehouse conduct to a risk area of lethal effect thresholds covering all storage zone. Outside the gas storage warehouse all interest points are more protected. But, the gauge EG20 in the direct line of propagation of shock wave outside conducts to an overpressure in the same order of magnitude as that the result in free field. It is necessary to be careful. Effectively, the study shows that the analysed points are situated in area of irreversible effects for human health. The comparison of numerical and experimental results for four sensors location inside the structure initially showed that AUTODYN software accurately modelled the propagation of a Mach stem along the inner walls of the warehouse. But nonetheless, the numerical results varied from the experimental results concerning incident overpressures when an obstacle was located between the explosive charge and the point of interest. Indeed, the passage of the incident shock wave through the bottle crates and the resulting multiple reflections were not correctly computed. In a future research, a finer mesh would be necessary to cope with this problem given that the interstitial gap between two bottles was just around 9 mm. The mesh size used for calculations was 5 mm, which meant that fewer than two mesh cells were present between the bottles. A refined grid would thus make it possible to more accurately represent reflections taking place in the centre of gas bottles. Nevertheless, variations in terms of overpressure were still reasonable given the mesh size used for these simulations. In conclusion, this work represents an experimental and numerical contribution concerning the interaction of shock waves in a representing storage of gas on an industrial plan. The interest of the experiments at small scale is not only to be able to validate computer codes but also to be able to analyse the peaks of overpressure and the coupling with the structure by the presence of obstacle (bottle crate, walls).

15/00069 Gas wells chemical stimulation – experimental design and field optimization

Ahmadi, M. and Yuan, C. *Journal of Petroleum Science and Engineering*, 2014, 113, 36–45.

Retrograde condensation in gas reservoirs leads to long-term loss of condensate and short-term liquid blocking, both of which cause a reduction in well productivity. The problem of loss of condensate was recognized long ago, while that of liquid blocking was not rigorously investigated until recently. Recent efforts have led to a better understanding of the liquid-blocking problem, and numerous approaches, with varying degrees of success, have been proposed to mitigate its effects. Based on the results of a large number of experimental measurements and a few reported field trials, near-wellbore chemical stimulation seems a viable solution to the liquid-blocking problem, though more successful field examples need to be reported for this technology to become a well-established and reliable practice for industry. The main characteristic of the treatment is its effectiveness in bonding to the rock surface and permanently altering its wettability toward non-wetting. Many difficulties arise when evaluating the possible chemicals available for this purpose, especially when the final objective is to design a field trial. A considerable number of papers have been published on the topic, but a publication that combines all the details is lacking. It is extremely important to know the physics behind this treatment approach and have a clear understanding of the key parameters profoundly affecting the outcome of evaluation and decision-making. Development of this knowledge will produce a better assessment of results and a thoughtful decision that reduces the risk of failure for field trials. This paper provides a stepwise procedure for correct evaluation and design of chemical treatment, starting with lab measurement designs and followed by simulation and economic optimization, all of which will help save time, effort, and money. Additionally, this paper highlights the necessary details that should be considered at each stage.

15/00070 Improved cost models for optimizing CO₂ pipeline configuration for point-to-point pipelines and simple networks

Knoope, M. M. J. *et al. International Journal of Greenhouse Gas Control*, 2014, 22, 25–46.

In this study, a new cost model is developed for CO₂ pipeline transport, which starts with the physical properties of CO₂ transport and includes different kinds of steel grades and up-to-date material and construction costs. This pipeline cost model is used for a new developed tool to determine the configuration leading to the lowest leveled costs for CO₂ transport, for point-to-point pipelines as well as for simple networks on different types of terrain and for different time frames. The model optimizes inlet pressure, diameter, steel grade and number of pumping stations. Results show that gaseous CO₂ transport can give lower leveled costs than liquid CO₂ transport for point-to-point pipelines and for simple networks, if the CO₂ is stored in a reservoir with a low required injection pressure, like depleted natural gas fields. However, for storage fields with a required injection pressure of 8 MPa or higher (like aquifers), CO₂ can be better transported in a liquid form. For onshore pipelines transporting liquid CO₂, the optimal inlet pressure is 9–13 MPa and pumping stations are installed roughly every 50–100 km. For offshore pipelines, pumping stations are not an option and the inlet pressure is determined by the length of the pipeline. The maximum inlet pressure is about 25 MPa and for even longer pipelines, a larger diameter is selected. The leveled costs (excluding initial compression) for transporting 100 kg/s (about 3 Mt/y) over 100 km are between 1.8 and €3.3/t for liquid and €4.0–6.4/t for gaseous CO₂ transport. For larger mass flows the costs are decreasing, for instance transporting 200 kg/s (about 6 Mt/y) over 100 km are €1.2–1.8/t for liquid and €3.0–3.8/t for gaseous CO₂ transport. Furthermore, results show that higher steel grades lead to lower investment costs for onshore pipelines transporting liquid CO₂. Using X120 in the long term reduces the pipeline costs up to 17%. For gaseous CO₂ transport, lower steel grades (like X42 and X52) are the best option. Also offshore pipelines do not benefit from the development of higher steel grades over time because the thickness should be at least 2.5% of the outer diameter. The results indicate that oversizing the pipeline, to transport CO₂ from an additional source that is coming available later, is not always cost-attractive. This strongly depends on the time span of which further CO₂ sources are available and on the mass flows. Oversizing appears earlier cost-attractive compared to two point-to-point pipelines if the source with the largest mass flow becomes available first.

15/00071 Predicting energy consumption of multiproduct pipeline using artificial neural networks

Zeng, C. *et al. Energy*, 2014, 66, 791–798.

This study uses artificial neural networks to forecast the daily electricity consumption of a multiproduct pipeline which is used to drive oil pumps. Forecasting electricity energy consumption is complicated since there are so many parameters affecting the energy consumption. Two different sets of input vectors are selected from these parameters by detailed analysis of energy consumption in this study, and two corresponding multilayer perceptron artificial neural network (MLP ANN) models are developed. To enhance the generalization ability, the numbers of hidden layers and neurons, activation functions and training algorithm of each model are optimized by the trial-and-error process step by step. The performances of the two proposed MLP ANN models are evaluated on real data of a Chinese multiproduct pipeline, and compared with two linear regression and two support vector machine models which are produced using different inputs. Results show that the two MLP ANN models have very high accuracy for prediction and better forecasting performance than the other models. The proposed input vectors and MLP ANN models are useful not only in the effective evaluation of batch scheduling and pumping operation, but also in the energy consumption target setting.

15/00072 Sensitivity analysis of hydraulic fracture geometry in shale gas reservoirs

Yu, W. *et al. Journal of Petroleum Science and Engineering*, 2014, 113, 1–7.

The combination of horizontal drilling and multiple hydraulic fracturing has been widely used to stimulate shale gas reservoirs for economical gas production. Numerical simulation is a useful tool to optimize fracture half-length and spacing in a multistage fracturing design. The authors developed a methodology to use a commercial reservoir simulator to simulate production performance of shale gas reservoirs after fracturing. They verified the simulation method with the available field data from the Barnett Shale. A sensitivity study of gas production for a shale gas well with different geometries of multiple transverse hydraulic fractures was performed, in which fractures' half-lengths vary. Hydraulic fractures are divided into two outer and inner fracture groups. The simulation results revealed that the outer fractures contribute more to gas production when fracture spacing is small due to the effect of fracture interference. Also, the

effects of fracture half-length and fracture spacing on gas production were studied. This work can provide some insights into characterization of hydraulic fracture geometry on the basis of production data in shale gas reservoirs.

15/00073 Theoretical and experimental determination of initial reservoir fluid in a lean gas condensate reservoir

Bonyadi, M. *et al. Journal of Petroleum Science and Engineering*, 2014, 114, 74–81.

In this work, a new theoretical and experimental method has been proposed to obtain initial reservoir fluid from well head separator samples in a depleted lean gas condensate reservoir. Condensate stabilization technique (CST) is a new recombination method based on simultaneous matching of dew point pressure and gas condensate ratio of initial reservoir fluid. The proposed method is applied to a real lean gas condensate reservoir in Iran, namely Jahroom. The modified Esmailzadeh–Roshanfekr equation of state and the Genetic Algorithm in MATLAB environment are used to simulate the CST method. The reservoir depletion process has been simulated by the constant volume depletion test. For nine pressure steps in the CVD test the proposed method was applied on separator samples. The average absolute deviation for composition of the recombined samples was found to be less than 3.5%. The proposed method was also experimentally checked by applying on the Jahroom separator samples. The experimental results show that the absolute deviation of 3.5% for the gas–condensate ratio and 1.72% for the dew point pressure are achieved. Additionally, the average absolute deviation for composition of the recombined sample was found to be 4%. The results of calculation and experiment show that the proposed recombination method can produce a fluid with a similar phase behaviour of initial reservoir fluid with an acceptable accuracy.

15/00074 Thermally regulated cylinder for adsorption storage of a hydrogenous gas

Vasiliev, L. L. *et al. International Journal of Heat and Mass Transfer*, 2014, 71, 125–132.

A real alternative to a standard cylinder with compressed hydrogen or methane is the adsorption technology of a storing these gases at moderate pressures of 3.5–6 MPa. A thermally regulated heat pipe-based cylinder intended for on-board storage of a hydrogenous gas in an adsorbed form is described. A two-dimensional numerical model of heat and mass transfer and sorption processes in such a cylinder is suggested. The fins and heat pipe shell were used as part of the computational domain. Simulations of gas charging and discharging are performed using the commercial finite volume flow solver Fluent on ANSYS. An experimental setup has been developed and data on the dynamic behaviour of the carbon fibrous material-packed cylinder with hydrogen have been obtained and compared with calculations. The results of this work can be used in designing systems for adsorptive storage of hydrogen or methane that are of interest for power engineering, transport, and private usage.

15/00075 Unaccounted for gas in natural gas transmission networks: prediction model and analysis of the solutions

Arpino, F. *et al. Journal of Natural Gas Science and Engineering*, 2014, 17, 58–70.

One of the main issues in the management and control of natural gas (NG) transmission networks is represented by unaccounted-for-gas (UAG), that is the quantity to be necessarily considered in the network balancing equation to take into account the unavoidable measuring errors. Even though this aspect has been continuously investigated in the scientific literature, few studies are available concerning UAG sources and related uncertainty estimation by considering pipelines typology, operative and environmental conditions, metrological performance of the installed measuring systems, procedures used to perform the network balancing and to estimate each term of the balancing equation including the losses and line-packs terms. In this paper the authors investigate the UAG sources and evaluate the criticalities related to UAG estimation–prediction, besides the possible actions aimed at reducing UAG quantity in different NG transmission networks. To this purpose, the authors investigate the UAG in some relevant NG transmission networks, statistically analysing annual and monthly trends of UAG and evidence UAG sources, with particular reference to the influence of the uncertainty of the measuring plants. In fact, inaccurate measurements can be responsible of large UAG, with potentially significant economic losses for all players in the system. Finally, the authors point out that the main UAG sources are related to some systematic measurement errors associated to climatic conditions and propose a simplified model to predict UAG value.

15/00076 Validation of 1D flow model for high pressure offshore natural gas pipelines

Helgaker, J. F. *et al. Journal of Natural Gas Science and Engineering*, 2014, 16, 44–56.

Transportation of natural gas through high pressure large diameter offshore pipelines is modelled by numerically solving the governing equations for one-dimensional compressible pipe flow using an implicit finite difference method. The pipelines considered have a diameter of 1 m and length of approximately 650 km. The influence of different physical parameters which enter into the model are investigated in detail. These include the friction factor, equation of state and heat transfer model. For high pressure pipelines it is shown that the selection of the equation of state can have a considerable effect on the simulated flow results, with the recently developed GERG 2004 being compared to the more traditional SRK, Peng–Robinson and BWR equations of state. Also, including heat accumulation in the ground is important in order to model the correct temperature at the outlet of the pipeline. The flow model is validated by comparing computed results to measured values for an offshore natural gas pipeline.

Economics, business, marketing, policy

15/00077 A new numerical formulation of gas leakage and spread into a residential space in terms of hazard analysis

Nagaosa, R. S. *Journal of Hazardous Materials*, 2014, 271, 266–274.

This study proposes a new numerical formulation of the spread of a flammable gas leakage. A new numerical approach has been applied to establish fundamental data for a hazard assessment of flammable gas spread in an enclosed residential space. The approach employs an extended version of a two-compartment concept, and determines the leakage concentration of gas using a mass-balance based formulation. The study also introduces a computational fluid dynamics (CFD) technique for calculating three-dimensional details of the gas spread by resolving all the essential scales of fluid motions without a turbulent model. The present numerical technique promises numerical solutions with fewer uncertainties produced by the model equations while maintaining high accuracy. The study examines the effect of gas density on the concentration profiles of flammable gas spread. It also discusses the effect of gas leakage rate on gas concentration profiles. The results showed that the gas flow velocities depend strongly on gas density, since the spread velocities are intensified by the density difference of the leaked gas and ambient air. This study also demonstrated the effect of the leakage rate on the gas spread. While the present numerical modelling is useful to obtain the concentration profiles of the leaked flammable gas, additional information is needed to assess the hazard posed by gas leakage. Efforts need to be made to link the concentration profiles predicted by the numerical modelling to the assessment by evaluating the possibility of ignition to the leaked gas. The present numerical modelling does not introduce a turbulent model to compute the concentration profiles of the leaked gas. The results of the numerical predictions have not been validated by using a series of laboratory experiments. Validations of the present numerical results by laboratory and *in situ* measurements should be provided in the near future.

15/00078 Chemical and toxicological properties of emissions from CNG transit buses equipped with three-way catalysts compared to lean-burn engines and oxidation catalyst technologies

Yoon, S. *et al. Atmospheric Environment*, 2014, 83, 220–228.

Chemical and toxicological properties of emissions from compressed natural gas (CNG)-fuelled transit buses with stoichiometric combustion engines and three-way catalyst (TWC) exhaust control systems were measured using a chassis dynamometer testing facility and compared to the data from earlier CNG engine and exhaust control technologies. Gaseous and particulate matter emissions from buses with stoichiometric engines and TWC were significantly lower than the emissions from buses with lean-burn engines. Carbonyls and volatile organic compounds (VOCs) from buses with stoichiometric engines and TWC were lower by more than 99% compared to buses with lean-burn engines. Elemental and organic carbons (EC and OC), polycyclic aromatic hydrocarbons (PAHs), and trace elements from buses with stoichiometric engines and TWC were effectively controlled and significantly lower than the emissions from buses with lean-burn engines. Potential mutagenicity measured using a microsphere modification of the Salmonella/microsome assay was lower by more than 99% for buses with stoichiometric engines and TWC, compared to buses with lean-burn engines and oxidation catalyst.

15/00079 Continuous performance assessment and improvement of integrated HSE and maintenance systems by multivariate analysis in gas transmission units

Azadeh, A. *et al. Journal of Loss Prevention in the Process Industries*, 2014, 27, 32–41.

In this study, an integrated health, safety and environment (HSE), and maintenance systems are presented. Multivariate analysis is used for continuous performance assessment and improvement of these systems. The two subjects of maintenance system and HSE have been individually investigated several times in different studies. However, few studies have been done to integrate these two systems and provide an integrated system for their implementation. This study evaluates current maintenance and HSE systems of a gas transmission unit by data envelopment analysis (DEA) and principal component analysis (PCA). Moreover, decision-making units (DMUs) are examined and ranked. Employees are considered as DMUs. This is done through investigating and measuring their efficiencies and identifying the inefficient and less-efficient units. Since an increase in the number of inputs does not lead to an increase in the number of outputs with the same scale, an output-oriented DEA with a variable returns to scale (VRS) is used. The fuzzy DEA is also used in this research to decrease uncertainty existing in qualitative indicators and human error. Finally, suggestions are given to improve those DMUs. The managers and employees of the gas transmission unit constitute the statistical population of the study. To achieve the objectives of this study, standard questionnaires with respect to HSE and maintenance systems are completed by operators. The proposed approach would help policy makers and top managers of gas transmission companies to have a more comprehensive and thorough understanding the working conditions with respect to the maintenance and HSE features.

15/00080 Development of natural gas as a vehicular fuel in Pakistan: issues and prospects

Khan, M. I. and Yasmin, T. *Journal of Natural Gas Science and Engineering*, 2014, 17, 99–109.

In a step towards adopting environment friendly fuel and to save foreign exchange, compressed natural gas (CNG) was introduced by the government of Pakistan in the country in 1992. Due to available price differential between CNG and gasoline/diesel and investor friendly policy and regulatory framework, CNG sector has shown tremendous growth over the last 10 years in the country. This growing demand of natural gas by CNG sector, results in gas shortages in the country. This paper describes the key steps in the development of CNG as transportation fuel in Pakistan. The present scenario of the CNG industry including the natural gas vehicles (NGVs) population growth and the expansion of CNG refilling stations are discussed. Various aspects of the CNG programme in Pakistan, for example environmental benefits, economic benefits and problems associated with CNG industry of Pakistan are illustrated.

15/00081 Energy and exergetic dissection of a natural gas sweetening plant using methyldiethanol amine (MDEA) solution

Banat, F. *et al. Journal of Natural Gas Science and Engineering*, 2014, 16, 1–7.

Demand of natural gas is increasing as it is cheaper than oil and a clean fuel. Natural gas contains impurities like water, CO₂, H₂S, COS, mercury and N₂. Amines processes are the developed technology available today for the removal of acid gases (CO₂ and H₂S). N-methyldiethanolamine is a well-known tertiary amine and selectively used to remove mostly H₂S from natural gas. Heat transfer has a huge role in many operational units of gas sweetening plant. The exergy method of analysis provides this true measure of effective energy use through its application of principles of both the first and second laws of thermodynamics. The present investigation involves development of a gas sweetening unit using process simulator ProMax. The results showed that the unit with highest value of exergy destruction was absorber (3 MW) followed by sweet gas air cooler (2.7 MW) and flasher unit (2.2 MW). Energy and exergy efficiencies determined revealed that absorber was the most efficient process with energy and exergy efficiencies of about 94% and 98% respectively. The flasher, air coolers and pressure recovery turbine were determined to be the under performers with exergy efficiencies of 27%, 24% and 31%, respectively. A further breakdown of exergy losses revealed that the chemical exergy losses are much higher than the physical exergy losses, contributing around 94% of the total exergy losses.

15/00082 Exposure pathways related to shale gas development and procedures for reducing environmental and public risk

Ziemkiewicz, P. F. *et al. Journal of Natural Gas Science and Engineering*, 2014, 16, 77–84.

Hydraulic fracturing, combined with horizontal well development, has resulted in rapid expansion of gas production in the Appalachian Marcellus shale formation. In the past 3 years, over 2000 horizontal/hydraulic fracture (HHF) wells have been developed in Pennsylvania, presenting significant potential for environmental degradation and human health risk if wastes are not isolated and handled properly. This study examined the waste streams from HHF development in the Marcellus formation and proposes protective measures that would

minimize exposure. The results showed that flowback, drilling muds, and HHF fluids all exceeded SDWA limits to varying degrees. Due to the contaminants found in these substances, proper handling and containment is essential to prevent harm to the environment. Field evaluations on a subset of pits and impoundments indicated several construction and maintenance deficiencies related to the containment systems and transport pipelines. The geomembrane liners were evaluated for tears and anchoring deficiencies, while liquid transfer pipes were assessed for bracing support against rupture. An out-of-sample probability analysis using the binomial distribution identifies trends to focus field construction and maintenance efforts in order to minimize exposure pathways of frac fluids to the environment.

15/00083 Forum shopping for ex-post gas-balancing services

Keyaerts, N. and D'haeseleer, W. *Energy Policy*, 2014, 67, 209–221.

The patchwork of different imbalance-settlement rules in geographically adjacent gas regions induces shippers to go 'forum shopping' to minimize costs of *ex post* balancing services. This shopping increases efficiency, and thus welfare of the shippers, on the one hand. The impact on net efficiency is dependent on the relative incentives provided by different balancing mechanisms and the relative system-balancing costs that the transmission-system operators face to offer balancing services to unbalanced shippers, on the other hand. If the gas-balancing mechanism and the system-balancing costs are aligned, net efficiency in the combined gas system will rise. The results demonstrate that such an outcome is not guaranteed. Hence, market integration without properly checking compatibility of balancing rules can improve shipper efficiency at the cost of reducing overall efficiency. The latter outcome should clearly be avoided by policy makers and European regulators whose primary concern should be overall efficiency as this provides fair and efficient prices for gas consumers and a higher utility for society.

15/00084 From shale gas to renewable energy based transportation solutions

Mallapragada, D. S. *et al. Energy Policy*, 2014, 67, 499–507.

This study presents an energy roadmap for the US light duty vehicle (LDV) sector that efficiently utilizes natural gas (NG) and transitions to renewable energy and carbon sources as they become economical. Well-to-wheels (WTW) efficiency was used to compare alternative NG transportation pathways. If internal combustion engine vehicles (ICEVs) remain prevalent, then compressed NG (CNG) is the favoured fuel. Among electric powertrains, centralized electricity generation with battery electric vehicle (BEV) is more efficient than on-board generation with fuel-cell vehicles (FCV). Plug-in hybrid electric vehicles (PHEVs) balance driving range against WTW efficiency, and provide flexibility in sourcing electricity from different energy sources. Despite these efficient WTW pathways, supplying NG for the LDV sector is estimated to decrease the lifetime of current US NG reserves to about 60 years. Beyond this period, compressed methane derived from biomass can replace CNG, and utilize the would-be developed CNG infrastructure. The LDV biomass requirement depends on the biomass to methane carbon conversion and battery storage capacity of CNG PHEVs. Converting biomass to methane using solar heat/H₂ leads to ~65% lower LDV biomass requirement compared to standalone processes recovering ~30% biomass carbon as methane. The resulting biomass amounts compare favourably with future US biomass supply projections.

15/00085 Genetic programming prediction of the natural gas consumption in a steel plant

Kovačič, M. and Šarler, B. *Energy*, 2014, 66, 273–284.

The Energy Agency of the Republic of Slovenia regulates and determines the operations of the natural gas market, charges for related gas imbalances, decides on suppliers and controls penalty provisions relating to breaches of stipulated provisions. Each supplier regulates and determines the charges for the differences between the ordered (predicted) and the actually supplied quantities. Štore Steel Company is one of the major spring-steel producers in Europe. Its natural gas consumption represents approximately 1.1% of Slovenia's national natural gas consumption. The company is contractually bound to a supplier which exacts penalties according to the differences mentioned above. A successful approach to gas consumption prediction is elaborated in this paper, with the aim of minimizing associated costs. In the attempt to model and predict the gas consumption and, accordingly, to minimize ordered and supplied gas quantity error, linear regression and the genetic programming approaches were used. The genetic programming model performs approximately two times more favourably. The developed gas consumption model has been used in practice since April 2005. The results show good agreement between the model-based ordered quantities and the actually supplied quantities, with savings amounting to approximately €100,000 per year.

15/00086 Hybrid system with an integrated CHP plant fueled by H₂NG blends: theoretical energy-environmental analysis and foreseeable optimizations

de Santoli, L. *et al. Energy and Buildings*, 2014, 71, 88–94.
Every technological innovation aimed at improving energy efficiency needs a sustainable development approach contributing to the decoupling process between environmental pollution and economic growth. The main aim of this paper is to demonstrate how the use of the hydrogen enrichment in a combined heat and power (CHP) plant represents a valid alternative to the same commercial energy systems, regarding to CO₂ emissions avoidance. The paper presents an energy–environmental analysis related to the use of renewable hydrogen (produced by a photovoltaic array) for eco-fuels production. Analysis of different hybrid systems configurations, based on a demo CHP (internal combustion engine) fuelled with hydrogen-enriched methane (natural gas, NG) blends, installed at the Sapienza University sports centre, Rome, Italy, were carried out. A theoretical energy analysis of these hybrid systems, with an integrated CHP plant, was developed in order to evaluate the energy penalty related to this carbon avoidance technique. Finally, an environmental comparison between conventional CHP system, hybrid system and hybrid system with separated electrical generation was performed. The results show that using blends with 20% of H₂ content and tuning engine parameters, it is possible to minimize the hybrid system energy efficiency loss and to obtain the best carbon avoidance performances (about 32% respect to conventional CHP).

15/00087 Improving the residential natural gas consumption forecasting models by using solar radiation

Soldo, B. *et al. Energy and Buildings*, 2014, 69, 498–506.
Natural gas is known as a clean energy source used for space heating in residential buildings. The residential sector is a major natural gas consumer that usually demands significant amount of total natural gas supplied in distribution systems. Since demands of all consumers should be satisfied and distribution systems have limited capacity, accurate planning and forecasting in high seasons has become critical and important. In this paper, the influence of solar radiation on forecasting residential natural gas consumption was investigated. Solar radiation impact was tested on two data sets, namely on natural gas consumption data of a model house, and on natural gas consumption data of a local distribution company. Various forecasting models with one-day ahead forecasting horizon were compared in this study, including linear models (auto-regressive model with exogenous inputs, stepwise regression) and non-linear models (neural networks, support vector regression). Results confirmed that solar radiation clearly influences natural gas consumption, and included as input variable in the forecasting model improves the forecasting results. Consequently it is recommended to use solar radiation as input variable in building forecasting models.

15/00088 The role of energy conservation and natural gas prices in the costs of achieving California's renewable energy goals

Considine, T. and Manderson, E. *Energy Economics*, 2014, 44, 291–301.
This paper develops an econometric forecasting system of energy demand coupled with engineering–economic models of energy supply. The framework is used to quantify the energy and environmental impacts of renewable and natural gas based electricity power generation in California, considering the role of on-going energy conservation efforts and incorporating different natural gas price scenarios over the forecast horizon (2011–2035). The results indicate that, relative to a business-as-usual scenario of continuing to rely on imported electricity to meet future demand, California's renewable portfolio standard (RPS) of 33% renewables by 2020 will increase electricity rates by over 10%. However, the RPS will also provide substantial annual savings in carbon dioxide emissions, equal to 40 million metric tonnes in 2020. Continuing non-price induced energy conservation at the historical rate will only result in a marginal reduction in electricity rates, although lower electricity use means that substantial savings are nonetheless achieved in electricity expenditures. In addition, continuing trend energy conservation leads to substantial savings in carbon dioxide emissions. Like the RPS, developing domestic natural gas generation also leads to rate increases and reductions in carbon dioxide emissions (relative to the baseline). However, these impacts are minor compared to the RPS scenario.

15/00089 The role of natural gas consumption and trade in Tunisia's output

Farhani, S. *et al. Energy Policy*, 2014, 66, 677–684.
This paper examines the impact of natural gas consumption, real gross fixed capital formation and trade on the real gross domestic product (GDP) in the case of Tunisia over the period 1980–2010. An autoregressive distributed lag bounds testing approach was used to test for cointegration between the variables. The Toda–Yamamoto

approach was then used to test for causality. The findings indicate the existence of a long-term relationship between the variables. Natural gas consumption, real gross fixed capital formation and trade add in economic growth. Natural gas consumption, real gross fixed capital formation and real trade cause real GDP in Tunisia. These findings open up new insights for policymakers to formulate a comprehensive energy policy to sustain economic growth in the long term.

Derived gaseous fuels

15/00090 Effects of various operational parameters on biomass gasification process; a modified equilibrium model

Ghassemi, H. and Shahsavani-Markadeh, S. *Energy Conversion and Management*, 2014, 79, 18–24.

In this paper by means of a modified equilibrium model based on Gibbs free energy minimization, performance of biomass gasification process is studied. Effects of parameters such as equivalence ratio, gasification temperature, fuel type and its moisture content, and gasifying agent, are investigated. Model results show that temperature has significant influence on cold gas efficiency more remarkably at lower temperature and has negligible effect on syngas heating value. Enriching the air with O₂ increases gas higher heating value (HHV) and for larger amount of oxygen it shows a maximum as equivalence ratio increases. Cold gas efficiency for higher oxygen amount is larger and its maximum obtained at lower equivalence ratio. By increasing the H/C molar ratio of biomass, cold gas efficiency increases but biomass O/C ratio shows adverse effect. Moisture content of biomass has negative effects on cold gas efficiency and HHV. For higher equivalence ratio this negative effect decreases.

15/00091 Fast microwave-assisted catalytic gasification of biomass for syngas production and tar removal

Xie, Q. *et al. Bioresource Technology*, 2014, 156, 291–296.

In this study, a microwave-assisted biomass gasification system was developed for syngas production. Three catalysts including Fe, Co and Ni with Al₂O₃ support were examined and compared for their effects on syngas production and tar removal. Experimental results showed that microwave is an effective heating method for biomass gasification. Ni/Al₂O₃ was found to be the most effective catalyst for syngas production and tar removal. The gas yield reached above 80% and the composition of tar was the simplest when Ni/Al₂O₃ catalyst was used. The optimal ratio of catalyst to biomass was determined to be 1:5–1:3. The addition of steam was found to be able to improve the gas production and syngas quality. Results of X-ray diffraction analyses demonstrated that Ni/Al₂O₃ catalyst has good stability during gasification process. Finally, a new concept of microwave-assisted dual fluidized bed gasifier was put forward for the first time in this study.

15/00092 High quality fuel gas from biomass pyrolysis with calcium oxide

Zhao, B. *et al. Bioresource Technology*, 2014, 156, 78–83.

The removal of CO₂ and tar in fuel gas produced by biomass thermal conversion has aroused more attention due to their adverse effects on the subsequent fuel gas application. High quality fuel gas production from sawdust pyrolysis with CaO was studied in this paper. The results of pyrolysis–gas chromatography/mass spectrometry (Py-GC/MS) experiments indicate that the mass ratio of CaO to sawdust (Ca/S) remarkably affects the behaviour of sawdust pyrolysis. On the basis of Py-GC/MS results, one system of a moving bed pyrolyser coupled with a fluid bed combustor has been developed to produce high quality fuel gas. The lower heating value of the fuel gas was above 16 MJ/N m³ and the content of tar was under 50 mg/N m³, which is suitable for gas turbine application to generate electricity and heat. Therefore, this technology may be a promising route to achieve high quality fuel gas for biomass utilization.

15/00093 H₂ recovery and CO₂ capture after water–gas shift reactor using synthesis gas from coal gasification

Lee, S.-W. *et al. Energy*, 2014, 66, 635–642.

In this study, a combined test of the water–gas shift (WGS) reactor and a Pd-based composite membrane was carried out for pre-combustion CO₂ capture in a coal gasifier. The two series of WGS reactions, i.e. a high-temperature shift and a low-temperature shift, were performed under a gas composition of 60% CO and 40% H₂ at 2100 kPa to imitate coal gasification. The CO₂ enrichment and H₂ recovery tests at 673 K and 2100 kPa with the high-pressure membrane module after the WGS reaction presented the enriched CO₂ concentration and H₂ recovery ratios of ~92% and ~96%, respectively. The long-term stability test showed that the CO₂ concentration decreased to 78.2%, and CO was

generated and reached to 8.8% in the retentate stream after 47 h because of reverse WGS and CO₂ hydrogenation reaction on 316L stainless steel module. The stability test for ~3137 h showed that these catalytic activities could be successfully prevented using steel with higher Cr and Ni contents, such as 310S. The WGS–membrane combination test using the outlet gas from a real coal gasifier was continued for ~100 h and showed that the WGS catalysts and membrane module made of 310S would be stable under real conditions.

15/00094 Methane conversion to syngas over Ni/Y₂O₃ catalysts – effects of calcination temperatures of Y₂O₃ on physicochemical properties and catalytic performance

Liu, H. *et al. Fuel Processing Technology*, 2014, 119, 81–86. Ni/Y₂O₃ catalysts, with Y₂O₃ prepared by the conventional precipitation method and calcined at different temperatures, were characterized by Brunauer–Emmett–Teller, temperature programmed reduction (TPR), X-ray diffraction, NH₃-temperature programmed desorption (TPD), CO₂-TPD and thermogravimetric analysis, and evaluated in the reaction of partial oxidation of methane. The results showed that, cubic phase Y₂O₃ could be obtained by calcinating the precursor at temperatures higher than 500 °C, and the specific surface area of Y₂O₃ was the largest when the calcination temperature was 500 °C. NH₃-TPD and CO₂-TPD profiles showed that, calcination temperature of Y₂O₃ influenced the amount of acidic and basic sites over Y₂O₃ support. After the loading of Ni, the strength and the amount of basic sites were almost the same over all the Ni/Y₂O₃ catalysts, which might be due to the hydrolysis of Y₂O₃ in the aqueous solution during the impregnation process. TPR results showed that, Y₂O₃ could be partially reduced, and the interactions between Ni and Y₂O₃ increased with the increase of Y₂O₃ calcination temperatures. In the reaction of partial oxidation of methane, all the Ni/Y₂O₃ catalysts were stable and exhibited high anti-carbon deposition ability.

15/00095 Moving bed syngas conditioning: modelling

Gómez-García, A. *et al. Applied Thermal Engineering*, 2014, 62, (2), 809–822.

This paper presents a modelling approach for simulating tars and particulate (dust) removal in a moving bed heat exchange filter (MBHEF) in order to satisfy gas requirements of end-use syngas applications: engines and turbines. The two-dimensional, adiabatic, steady-state proposed model accounts for two-phase (gas and solid) and neglects conduction and mass diffusion. Tars condensation is modelled through representative tar class lumps: phenol (class 2), naphthalene (class 4), pyrene (class 5). The model also considers tar concentration influence on the tar dew point. The filtration model is taken from literature. A sensitivity analysis is performed varying the particle size and the superficial gas velocity. Maps of temperature and tars abatement efficiency are presented. The simulation results indicate the feasibility of the use a MBHEF as tars removal equipment benefiting its advantages against others gas-cleaning methods with acceptable pollutant removal efficiencies, from 88% to 94% for the ranges studied. Results also point out low gas velocities (0.5–1 m/s) and high particle size (400–700 µm) for reducing operational costs in MBHEFs with compact size.

15/00096 Trace metals emission in syngas from biomass gasification

Pudasane, D. *et al. Fuel Processing Technology*, 2014, 120, 54–60.

In this paper, trace metals (As, Be, Cd, Cr, Hg, Ni, Pb, Se and V) emission from the atmospheric entrained flow gasifier REGA at Karlsruhe Institute of Technology, Germany is presented. Elemental composition and metals concentration in glycol (model fuel) and straw char samples were determined. In order to achieve well defined and reproducible operating conditions, gasification experiments were carried out with glycol and slurry (straw char mixed with glycol) as fuel. Trace metals emission and distribution into particle and gas phase in syngas from gasification were measured according to US Environmental Protection Agency method 29. During glycol gasification, metals concentration in syngas ranged from 0.1 (V) to 4.6 µg/Nm³ (Cr). In slurry gasification, metals concentration in syngas ranged from 2.4 (Hg) to 53.2 µg/Nm³ (Ni). Trace metals tend to volatilize more in reducing gasification environment. Tendency of metals to speciate into particle phase increased in slurry gasification than glycol gasification due to increases in particle concentration and unburned carbon content in syngas. The increase of particle and carbon content in syngas possessed strong influence in distribution behaviour of As, Be and Pb, however, such influence was less for other metals studied. Mercury in syngas was speciated predominantly into elemental form followed by oxidized form whereas share of particle bound mercury was the least.

LNG

15/00097 Automatically varying the composition of a mixed refrigerant solution for single mixed refrigerant LNG (liquefied natural gas) process at changing working conditions

Xu, X. *et al. Energy*, 2014, 64, 931–941.

The single mixed refrigerant (SMR) process is widely used in the small- and medium-scale liquefaction of natural gas. Operating the mixed-refrigerant process outside of the design specifications is difficult but essential to save energy. Nevertheless, it is difficult to realize because the process needs to alter the working refrigerant composition. To address this challenge, this study investigated the performance diagnosis mechanism for SMR process. A control strategy was then proposed to control the changes in working refrigerant composition under different working conditions. This strategy separates the working refrigerant flow in the SMR process into three flows through two-phase separators before it flows into the cold box. The first liquid flow is rich in the high-temperature component (isopentane). The second liquid flow is rich in the middle-temperature components (ethylene and propane), and the gas flow is rich in the low-temperature components (nitrogen and methane). By adjusting the flow rates, it is easy to decouple the control variables and automate the system. Finally, this approach was validated by process simulation and shown to be highly adaptive and exergy efficient in response to changing working conditions.

15/00098 Design and analysis of a small-scale natural gas liquefaction process adopting single nitrogen expansion with carbon dioxide pre-cooling

Yuan, Z. *et al. Applied Thermal Engineering*, 2014, 64, (1–2), 139–146.

With the growth of energy consumption and environmental protection concerns, it is of enormous economic and environmental values for the development of stranded gas. As a means for the exploitation and transportation of stranded gas to market, a novel small-scale liquefaction process adopting single nitrogen expansion with carbon dioxide pre-cooling is examined in this paper. Taking unit energy consumption as the target function, Aspen HYSYS is employed to simulate and optimize the process to achieve the liquefaction rate of 0.77 with unit energy consumption of 9.90 kW/kmol/h. Furthermore, the adaptability of this process under different pressure, temperature and compositions of feed gas is studied. Based on the optimization results, the exergy losses of main equipment in the process are evaluated and analysed in details. With a compact device, safety operation, simple capability, this liquefaction process proves to be suitable for the development of small gas reserves, satellite distribution fields of gas or coalbed methane fields.

15/00099 Pressure control of GLNG gas pipeline compliant with Australian standard requirements

Terenzi, A. and Clini, F. *Journal of Natural Gas Science and Engineering*, 2014, 17, 42–48.

The GLNG consortium, formed by Santos, Total, Petronas and Kogas, is planning a large-scale development to extract coal seam gas (CSG) from existing and future fields in the Roma, Fairview and Arcadia Valley area in Queensland, Australia and to supply that gas for commercial sale and/or conversion to liquefied natural gas (LNG). A gas transmission pipeline called the 'GLNG pipeline' is a major component of the development. The GLNG pipeline will be approximately 420 km in length and will be used to transport CSG from the existing and future fields to an LNG processing facility at Curtis Island near Gladstone (LNG plant). Three inlets are foreseen in the initial pipeline section: (1) F-PCS-01 at KP0, (2) future F-HCS-05 at KP12.4 and (3) future A-HCS-01 at KP52.3. The detailed engineering phase of the pipeline is under way and the construction activities started in 2013. This paper describes the process and flow assurance related characteristics of the GLNG pipeline pressure control system developed during detail engineering, compliant with the requirements established by the adopted design standard, i.e. AS2885.1. The control system, ensuring adequate overpressure protection, allows a safe operation taking care of envisaged pipeline operating pressure, close to maximum allowable operating pressure, and downward slope, causing risk for excessive pressurization of lower downstream sections.

15/00100 Thermal performance analysis of intermediate fluid vaporizer for liquefied natural gas

Pu, L. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 564–574.

The intermediate fluid vaporizer (IFV) is a new kind of vaporizer for liquefied natural gas (LNG). A thermal model was established based on the energy balance among the three typical parts of IFV, namely, evaporator, condenser and thermolator, whose mutual coupling and constraints were fully considered. Calculation codes were developed to solve the energy balance equations, in which the formulation of

experimental correlations and thermal property codes were incorporated into the iteration. The temperature, pressure and mass flow rate of the inlet LNG and seawater, as well as the heat transfer area of the three parts, were known parameters. The outlet temperature of natural gas (NG) and seawater, the surface and total heat transfer coefficients in the three parts, and the propane saturation temperature were the solution parameters. The effects of the temperature and mass flow of inlet seawater, the pressure, and mass flow rate of inlet LNG on the solution parameters were systematically investigated. The intrinsic link, in terms of the heat transfer performance inside the IFV, was revealed. The outlet temperature of seawater and NG increased with increased temperature and mass flow rate of the inlet seawater and with reduced inlet mass flow rate of LNG. The increased inlet pressure of LNG significantly improved the NG outlet temperature, but this increment has mild influence on the outlet temperature of seawater. The propane saturation temperature also increased with increased temperature and mass flow rate of inlet seawater and with reduced inlet LNG mass flow rate, whereas, it was not sensitive to the inlet LNG pressure.

15/00101 Thermodynamic analysis and optimization of a solar-powered transcritical CO₂ (carbon dioxide) power cycle for reverse osmosis desalination based on the recovery of cryogenic energy of LNG (liquefied natural gas)
Xia, G. *et al. Energy*, 2014, 66, 643–653.

A solar-powered transcritical CO₂ (carbon dioxide) power cycle for reverse osmosis desalination based on the recovery of cryogenic energy of liquefied natural gas (LNG) is proposed. The system consists of a solar collector subsystem, a transcritical CO₂ power cycle subsystem, a LNG subsystem and a reverse osmosis desalination subsystem. A thermal storage unit is introduced into the system to guarantee continuous and stable operation of the system. A mathematical model is developed to simulate the system based on several assumptions. The effects of several key thermodynamic parameters on the system performance are examined based on the performance criteria, including daily exergy efficiency, daily mechanical work output and daily fresh water output. Parametric optimization is conducted by genetic algorithm to maximize the daily fresh water output. The results show that the CO₂ turbine inlet pressure has an optimal value to reach the daily maximum exergy efficiency under the given conditions. The daily exergy efficiency could decrease with an increase in condenser temperature, and increase with an increase in mass flow rate of oil and natural gas turbine inlet pressure. Through parametric optimization, the system can reach the daily exergy efficiency of 4.90% and provide 2537.33 m³ fresh water per day under the given conditions.

15/00102 Thermodynamic analysis of a Brayton cycle and Rankine cycle arranged in series exploiting the cold exergy of LNG (liquefied natural gas)

Gómez, M. R. *et al. Energy*, 2014, 66, 927–937.

The liquefied natural gas (LNG) regasification process is a source of cold exergy capable of being exploited to improve the efficiency of energy conversion. This paper presents a novel power plant consisting of a combination of a closed Brayton cycle (CBC) with a steam Rankine cycle (SRC), arranged in series with regard to the power source, while exploiting the cold exergy available in the regasification process of LNG. The power plant is fuelled by a combustion system of natural gas where the flue gases firstly yield heat to the CBC, then to the SRC and finally to the combustion air by means of a heat recovery process. The LNG cold exergy is exploited to cool the helium used in the CBC to cryogenic temperatures at the compressor inlet as well as for generating electric power through direct expansion. The power plant is thermodynamically modelled and simulated using Engineering Equation Solver. An energy and exergy analysis is carried out to evaluate the effect of some key parameters on the efficiency such as the temperature at the compressor inlet, the compression ratio, the temperature at the CBC turbine inlet and the LNG pressure during the regasification process. The outcome is a high efficiency power plant.

Hydrogen generation and storage

15/00103 A comprehensive energy–exergy-based assessment and parametric study of a hydrogen production process using steam glycerol reforming

Hajjaji, N. *et al. Energy*, 2014, 64, 473–483.

Various assessment tools are applied to comprehensively investigate a glycerol-to-hydrogen production system. These tools investigate the chemical reactions, design and simulate the entire hydrogen production process, study the energetic and exergetic performances and perform parametric analyses (using intuitive and design of experiment-based methods). Investigating the chemical reaction of steam glycerol

reforming reveals that the optimal conditions, determined based on maximizing the hydrogen production while minimizing the methane and carbon monoxide contents and coke formation, can be achieved at a reforming temperature and a water-to-glycerol feed ratio (WGFR) of 950 K and 9, respectively. The thermal and exergetic efficiencies of the resulting process are 66.6% and 59.9%, respectively. These findings are lower than those cited in the literature and relative to other reformates (methane, ethanol and methanol). The parametric investigation indicates that the performance of the process (energetic and exergetic) could be ensured by using an appropriate and judiciously selected combination of the reactor temperature and WGFR. Based on the parametric energetic and exergetic investigation, WGFR = 6 and $T = 1100$ K appear to be the most accurate parameters for the entire glycerol-to-hydrogen process. For this recommended configuration, the thermal and exergetic efficiencies are 78.1% and 66.1%, respectively.

15/00104 A hybrid wind-PV system performance investigation for the purpose of maximum hydrogen production and storage using advanced alkaline electrolyzer
Khalilnejad, A. and Riahy, G. H. *Energy Conversion and Management*, 2014, 80, 398–406.

In this study, design and modelling of hybrid wind–photovoltaic (PV) system is done for the purpose of hydrogen production through water electrolysis. Actual data for weekly solar irradiation, wind speed, and ambient temperature of Sahand, Iran, are used for performance simulation and analysis of the system examined. The detailed model of components is used. The 10 kW alkaline electrolyser model, which produces hydrogen, is based on combination of empirical electrochemical relationships, thermodynamics, and heat transfer theory. The operation of this system is optimized using imperial competitive colony algorithm. The objective of optimization is to maximize hydrogen production, considering minimum production of average excess power. This system is analysed in three different conditions of using just wind turbine (WT), PV array, and combination of them as power source, producing hydrogen of 8297, 4592, and 10,462 mol, respectively. As for this result and with analysing other results of simulation, it is clarified that the hybrid system is more useful for this study. In hybrid form the ratio of average produced power to nominal power for PV array is 0.247 and for WT is 0.493 which demonstrates that WT is more effective in production.

15/00105 An integrated energy storage system based on hydrogen storage: process configuration and case studies with wind power

Gao, D. *et al. Energy*, 2014, 66, 332–341.

The interconnection between a renewable power generation facility and a power grid poses challenges because of volatility and intermittent characteristics. Energy storage is one of the best solutions for this problem. This paper presents an integrated energy storage system (ESS) based on hydrogen storage, and hydrogen–oxygen combined cycle, wherein energy efficiency in the range of 49–55% can be achieved. The proposed integrated ESS and other means of energy storage are compared. The results show that the proposed integrated system cannot be constrained by geological conditions and availability of materials, and appears to be an appropriate tool for the development of renewable power. Moreover, a case study is conducted for a special wind-power plant with a nominal power of 100 MW and that generates electricity of 225 GWh/y. The integrated system is designed based on the daily wind load. Energy efficiency and preliminary economic comparison studies for the integrated system operated in two modes show that up to 50% average net efficiency of the integrated ESS can be achieved and that the integrated ESS can stabilize the intermittent wind power. Therefore, the integrated ESS can be useful to mitigate the bottleneck of renewable power development.

15/00106 Direct bioconversion of raw corn stalk to hydrogen by a new strain *Clostridium* sp. FS3

Song, Z.-X. *et al. Bioresource Technology*, 2014, 157, 91–97.

A new strain FS3 which could achieve an efficient bioconversion of raw corn stalk to hydrogen had been isolated from anaerobic acclimated sludge, and identified as *Clostridium butyricum* on the basis of a series of physiological and biochemical experiments and 16S rDNA gene sequence. The strain could utilize various carbon sources to produce hydrogen. On the basis of single-factor experiments, the response surface methodology (RSM) was performed to optimize the media for hydrogen production. The maximum hydrogen yield of 92.9 ml/g was observed under the optimal conditions: 20 g/l raw corn stalk, 1.76 g/l NH₄HCO₃, 0.91 g/l KH₂PO₄ and 10.4 ml/l nutrient solution. This finding opens a new avenue for direct conversion of raw cellulosic biomass to bio-hydrogen.

15/00107 Effects of operating parameters on hydrogen production from raw wet steam-exploded cornstalk and two-stage fermentation potential for biohythane production

Liu, Z. *et al. Biochemical Engineering Journal*, 2014, 90, 234–238.
Biohythane (biohydrogen + biomethane) production from agricultural residue is a win-win solution for the supply of renewable energy and valorization of waste biomass. This study reported the first investigation on hydrogen fermentation directly using raw wet steam-exploded cornstalk (SC) without any further processing for drying or detoxification. The effects of key operating parameters (feedstock concentration, initial pH and heat treatment of seed sludge) were systematically studied. The suitable conditions for hydrogen fermentation from the wet SC were the feedstock concentration at 200 g L⁻¹ (TS, 6–8%), pH at 6.5 and seed sludge without heat treatment. In addition, compared to one-stage biomethane fermentation, the two-stage biohythane fermentation by integrating hydrogen fermentation with biomethane production from SC led to the hydrogen and methane yields of 12 and 195 L kg⁻¹ TS⁻¹, respectively, corresponding to an increased energy recovery of 26%, reduced fermentation time and facilitated conversion of volatile fatty acids. These results demonstrated the feasible energy-efficient biohydrogen or biohythane production from the wet steam-exploded cornstalk, implying the promising potential of this method for harvesting clean hythane vehicle fuel from agricultural biomass.

15/00108 Heavy metal recovery combined with H₂ production from artificial acid mine drainage using the microbial electrolysis cell

Luo, H. *et al. Journal of Hazardous Materials*, 2014, 270, 153–159.
The aim of this study was to utilize the microbial electrolysis cell (MEC) for metal removal from acid mine drainage (AMD) and simultaneous H₂ production. A dual-chamber MEC was developed to concurrently produce H₂ and remove Cu²⁺, Ni²⁺, and Fe²⁺ from AMD under single and mixed metal conditions. With an applied voltage of 1.0 V, Cu²⁺ in the AMD was prior to others to be recovered at the cathode, followed by Ni²⁺, and finally Fe²⁺. The H₂ production rates achieved during the AMD treatment were in the range of 0.4–1.1 m³ m⁻³ d⁻¹, and the highest rate was obtained with the AMD containing single Cu²⁺. The highest efficiency of cathode electron recovery reached 89%, which was obtained with the AMD containing mixed metals. The recovered electrons were used for both H₂ production and metal reduction. The energy recovery efficiency of MEC reached up to 100%, suggesting that H₂ generated from AMD was sufficient to offset the energy input during the treatment. The MEC was successfully applied to remove metals from the AMD, recover value-added products of Cu⁰ and Ni⁰, and to produce H₂.

15/00109 Hydrogen production from CO₂-free thermal decomposition of methane: design and on-sun testing of a tube-type solar thermochemical reactor

Abanades, S. *et al. Fuel Processing Technology*, 2014, 122, 153–162.
This study addresses the development of a solar thermochemical reactor for CO₂-free production of hydrogen from solar-aided methane decomposition. The developed laboratory-scale solar reactor basically pertaining to the indirect heating concept is chiefly based on a tube-type configuration in tandem with a cavity receiver. The reactor design and performance prediction were first appraised via three-dimensional computational fluid dynamics thermal simulation as a function of internal geometry. The model including coupled heat/mass transfer and chemical reaction aimed to simulate the reactor in order to determine the temperature distribution and the conditions for maximum reactor efficiency. The designed 1 kW solar reactor was then constructed and installed for reaction testing at the focus of a 2 m diameter parabolic solar concentrator. Solar CH₄ decomposition experiments were performed between 1300 and 1400 °C to demonstrate the feasibility of hydrogen production and the reliability of the solar process using the developed reactor concept, and the results were used to validate simulations. Regarding the estimated kinetic parameters, the best fitting was obtained for an activation energy of 320 kJ/mol and a pre-exponential factor of 10¹¹ s⁻¹. The chemical conversion was improved when increasing the temperature or decreasing the inlet gas flow rate or the CH₄ mole fraction. A maximum CH₄ conversion (respectively H₂ yield) of 90% (respectively 85%) was achieved at 1400 °C and the thermochemical reactor efficiency reached 5% for the highest CH₄ content in the feed.

15/00110 Hydrogen production from methane by DC spark discharge: effect of current and voltage

Moshrefi, M. M. and Rashidi, F. *Journal of Natural Gas Science and Engineering*, 2014, 16, 85–89.
Effects of current and voltage of consumed power on plasma reactor with rotating electrode at different feed flow rates is investigated for the non-thermal decomposition of methane using a system of direct current (DC) discharge. Experimental results showed that designed reactor increases not only the concentration of the produced hydrogen

in continues condition but also guarantees stable plasma. It is demonstrated that decreasing both electrical voltage and electrical current results in decreasing of methane conversion but on the other hand C₂ hydrocarbons selectivity will increase. After the break down voltage, increasing the input power results in increasing electrical current more intensively than increasing electrical voltage.

15/00111 ILC (ionic liquid colloids) based on p(4-VP) (poly(4-vinyl pyridine)) microgels: synthesis, characterization and use in hydrogen production

Sahiner, N. *et al. Energy*, 2014, 66, 256–263.
In this study, poly(4-vinyl pyridine) (p(4-VP)) colloidal ionic liquid particles derived from 4-vinyl pyridine (4-VP) are used in the preparation of a catalyst system by loading metal salts such as CoCl₂ and NiCl₂ from ethyl alcohol solutions into the modified p(4-VP) particles, and used for hydrogen generation from NaOH-free hydrolysis of NaBH₄. Colloidal ionic liquids containing 0.054 mmol Co and Ni were used in NaOH-free hydrolysis of 0.30 g NaBH₄ in 50 mL water at 40 °C and 1000 rpm mixing rate. The reaction rates relating to hydrolysis of NaBH₄ were 3148 (mL H₂) (min)⁻¹ (g of Co)⁻¹ for Co, and 1803 (mL H₂) (min)⁻¹ (g of Ni)⁻¹ for Ni. The effect of metal loading time, NaBH₄ concentration, temperature, and kinetic parameters were also investigated. The activation energy, enthalpy, and activation entropy for the reaction of NaBH₄ in the presence of the colloidal dicationic catalyst system were calculated as 43.98 kJ/mol, 40.38 kJ/mol and –178.22 J/mol K, respectively.

15/00112 Microwave plasma studies of Spirulina algae pyrolysis with relevance to hydrogen production

Lin, K. C. *et al. Energy*, 2014, 64, 567–574.
Growth of the hydrogen market has motivated increased study of hydrogen production. Understanding how biomass is converted to hydrogen gas can help in evaluating opportunities for reducing the environmental impact of petroleum-based fuels. Using an atmospheric-pressure microwave plasma reactor coupled with species-selective analysis, experiments are conducted at microwave power levels of 800, 900 and 1000 W, a reactant flow rate of 12 slm, and 1 g of dry Spirulina algae in nitrogen. At the absorbed microwave power levels used in this experiment, hydrogen gas produced is in the range of 36.75–45.13% volume fraction, 13.42–15.48 mg per minute, and 12.37–31.46 mg per gram of Spirulina algae consumed. Moreover, the selection of power levels demonstrates that 20.62–52.43% hydrogen atom mass content in dry algae is converted to hydrogen gas. In general, the effect of reaction temperatures on the gas product formation is qualitatively consistent with those produced from other biomass materials reported in literature. Overall, these results will help to expand the knowledge concerning Spirulina algae and hydrogen yield on the basis of microwave-assisted pyrolysis and reaction temperatures, which will inform the study and design of hydrogen production technologies.

15/00113 Modeling and simulation of an isolated hybrid micro-grid with hydrogen production and storage

Cau, G. *et al. Energy Procedia*, 2014, 45, 12–21.
This work relates the study of system performance in operational conditions for an isolated micro-grid powered by a photovoltaic system and a wind turbine. The electricity produced and not used by the user will be accumulated in two different storage systems: a battery bank and a hydrogen storage system composed of two proton exchange membrane (PEM) electrolyzers, four pressurized tanks and a PEM fuel cell. One of the main problems to be solved in the development of isolated micro-grids is the management of the various devices and energy flows to optimize their functioning, in particular in relation to the load profile and power produced by renewable energy systems depending on weather conditions. For this reason, through the development and implementation of a specific simulation program, three different energy management systems were studied to evaluate the best strategy for effectively satisfying user requirements and optimizing overall system efficiency. From real meteorological data, the behaviour of the system was studied for three different logics in two different weather conditions. The EM-A logic uses the state of battery charge as a control variable and shows the lowest use of the hydrogen system on the summer day and the use of the fuel cell when the batteries are completely discharged on the autumn day. This fact may give an excessive rigidity to the management system and make the fuel cell work not in the best conditions. With the constraint of operating only in the nominal condition for electrolyser and fuel cell, the EM-B strategy shows the highest use of the hydrogen storage system. In this case, a suitable hydrogen storage volume will be required to prevent complete filling and emptying of the tanks (such as in the autumn day case) resulting in unavailability of this storage system. Furthermore, this system shows the highest value of energy exchanged with the system at the end of the day (in absolute terms): in the autumn days it can cause major use of storage systems with increasing energy loss. Finally, the EM-C energy management strategy, which is based on the minimization of cost of energy, shows an interesting use of the

hydrogen storage system, in particular for the fuel cell, during periods of high power demand. With reference to the autumn scenario, the EM-C strategy leads to the best management with an amount of energy used to cover the deficit between supply and demand at the end of the day lower than in the other two cases. On the other hand, an energy management based on cost minimization is difficult to implement and can cause a continuous on/off status of the devices which may reduce their lifetime. More comparative elements between the different strategies can be derived by increasing the time horizon of more than a day or extending the analysis to other case studies (coming to an annual analysis).

15/00114 Progress in polymeric material for hydrogen storage application in middle conditions

Pedicini, R. *et al. Energy*, 2014, 64, 607–614.

Hydrogen sorption using a manganese oxide anchored to poly(ether-ether-ketone) matrix was studied. The functionalization process and the obtained results on hydrogen storage capability of the synthesized polymer are reported. The functionalized polymer was characterized by scanning electron microscopy, transmission electron microscopy, X-ray diffraction and volumetric hydrogen sorption measurements. Different synthesis conditions in terms of precursor concentration and reaction time were used and the direct correlation between manganese oxide percentage and hydrogen storage capability was confirmed. In this way different powders were synthesized. It is assumed that the sample with 78 wt% (SPMnO6) forms a combination of mixed manganese oxides since different reticular planes were observed. On this sample, promising results regarding to hydrogen capability at 110 °C and 60 bar were obtained, in particular 1.1 wt% hydrogen sorption was recorded. Moreover, this value, after about 30 h, remains quite constant. These preliminary results demonstrate the capability of such compound to absorb hydrogen, for this reason further morphological and structural studies are in progress with the aim to better understand the mechanism involving the storage.

15/00115 Thermodynamic investigation and environment impact assessment of hydrogen production from steam reforming of poultry tallow

Hajjaji, N. *Energy Conversion and Management*, 2014, 79, 171–179.

In this research, various assessment tools are applied to comprehensively investigate hydrogen production from steam reforming of poultry tallow (PT). These tools investigate the chemical reactions, design and simulate the entire hydrogen production process, study the energetic performance and perform an environment impact assessment using life cycle assessment (LCA) methodology. The chemical reaction investigation identifies thermodynamically optimal operating conditions at which PT may be converted to hydrogen via the steam reforming process. The synthesis gas composition was determined by simulations to minimize the Gibbs free energy using the Aspen Plus 10.2 software. These optimal conditions are, subsequently, used in the design and simulation of the entire PT-to-hydrogen process. LCA is applied to evaluate the environmental impacts of PT-to-hydrogen system. The system boundaries include rendering and reforming along with the required transportation process. The reforming inventories data are derived from process simulation in Aspen Plus, whereas the rendering data are adapted from a literature review. The life cycle inventories data of PT-to-hydrogen are computationally implemented into SimaPro 7.3. A set of seven relevant environmental impact categories are evaluated: global warming, abiotic depletion, acidification, eutrophication, ozone layer depletion, photochemical oxidant formation, and cumulative non-renewable fossil and nuclear energy demand. The results are subject to a systematic sensitivity analysis and compared to those calculated for hydrogen production from conventional steam methane reforming. The LCA results indicate that the thermal energy production process is the main contributor to the selected environmental impact categories. Improvement actions to minimize the reforming thermal energy and the transport distance are strongly recommended as they would lead to relevant environmental improvements.

04 BY-PRODUCTS RELATED TO FUELS

15/00116 Adsorption characteristics of selected hydrophilic and hydrophobic micropollutants in water using activated carbon

Nam, S.-W. *et al. Journal of Hazardous Materials*, 2014, 270, 144–152. This study investigated the adsorption characteristics of nine selected micropollutants (six pharmaceuticals, two pesticides, and one endocrine disruptor) in water using an activated carbon. The effects of

carbon dosage, contact time, pH, dissolved organic matter (DOM), and temperature on the adsorption removal of micropollutants were examined. Increasing carbon dosage and contact time enhanced the removal of micropollutants. Sorption coefficients of hydrophilic compounds (caffeine, acetaminophen, sulfamethoxazole, and sulfamethazine) fit a linear isotherm and hydrophobic compounds (naproxen, diclofenac, 2,4-D, triclocarban, and atrazine) fit a Freundlich isotherm. The removal of hydrophobic pollutants and caffeine were independent of pH changes, but acetaminophen, sulfamethazine, and sulfamethoxazole were adsorbed by mainly electrostatic interaction with activated carbon and so were affected by pH. The decrease in adsorption removal in surface water samples was observed and this decrease was more significant for hydrophobic than hydrophilic compounds. The decline in the adsorption capacity in surface water samples is caused by the competitive inhibition of DOM with micropollutants onto activated carbon. Low temperature (5 °C) also decreased the adsorption removal of micropollutants, and affected hydrophobic compounds more than hydrophilic compounds. The results obtained in this study can be applied to optimize the adsorption capacities of micropollutants using activated carbon in water treatment process.

15/00117 Influence of activation atmosphere used in the chemical activation of almond shell on the characteristics and adsorption performance of activated carbons

de Yuso, A. M. *et al. Fuel Processing Technology*, 2014, 119, 74–80.

The aim of this work was to compare the effect of different activating atmospheres on the final properties and adsorption performance of activated carbons. Almond shell based activated carbons have been obtained by chemical activation with phosphoric acid. Two sets of activated carbons were prepared. First set was prepared under inert atmosphere at different impregnation ratios, temperatures and times of activation. Second set of activated carbons was prepared at the same activating conditions except the activating atmosphere using an oxidant one. Activated carbons prepared under both activation atmospheres were characterized by elemental analysis (EA), thermogravimetry (TGA), temperature programmed desorption (TPD), point zero charge (PZC), Boehm titration and N₂ physisorption. To study the adsorption performance of the activated carbons toluene adsorption-desorption isotherms were determined gravimetrically. The results obtained confirm that the activating atmosphere has a strong influence on the final characteristics of the activated carbons. Activated carbons with higher oxygen content and more negative surface charge have been obtained by changing the activating atmosphere by an oxidant one. Surface area is also higher for activated carbons prepared under oxidant atmosphere. However toluene adsorption capacity is lower for activated carbons prepared under oxidant atmosphere due to their surface chemistry.

15/00118 Numerical and experimental evaluation of fly ash collection efficiency in electrostatic precipitators

Al-Hamouz, Z. *Energy Conversion and Management*, 2014, 79, 487–497.

This paper evaluates experimentally and numerically the influence of different geometrical and operating parameters of a single stage wire-duct electrostatic precipitators (WDEP) on its fly ash collection efficiency. The governing equations are solved under dust loading conditions using the finite element method (FEM) and a modified method of characteristics (MMC). In addition, a proto-type design that represents a WDEP was successfully designed and fabricated at the author's research institute. The experiments were carried out under laboratory conditions where the WDEP was made of Plexiglas with a length of 2 m, height of 1 m, wire-to-collecting plate spacing of 0.2–0.3 m, and an inter-electrode (wire-to-wire) spacing of 0.16–0.21 m. Smoke of fired coal was used as a source of seed particles of PM10 category (with 75–80% of particles lying below 10 µm). An indication of the effectiveness of the numerical approach was carried out through a comparison of computed results as well as presently and previously obtained experimental data.

15/00119 Quality and generation rate of solid residues in the boiler of a waste-to-energy plant

Allegrini, E. *et al. Journal of Hazardous Materials*, 2014, 270, 127–136.

The Danish waste management system relies significantly on waste-to-energy (WtE) plants. The ash produced at the energy recovery section (boiler ash) is classified as hazardous waste, and is commonly mixed with fly ash and air pollution control residues before disposal. In this study, a detailed characterization of boiler ash from a Danish grate-based mass burn type WtE was performed, to evaluate the potential for improving ash management. Samples were collected at 10 different points along the boiler's convective part, and analysed for grain size distribution, content of inorganic elements, polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD and PCDF), and leaching of metals. For all samples, PCDD and PCDF levels were below regulatory limits, while high pH values and leaching of Cl, for example, were critical. No significant differences were found between boiler ash from individual

sections of the boiler, in terms of total content and leaching, indicating that separate management of individual ash fractions may not provide significant benefits.

15/00120 Stability of functionalized activated carbon in hot liquid water

Van Pelt, A. H. *et al. Carbon*, 2014, 77, 143–154.

Acidity and stability of activated carbon-based solid acid catalysts for aqueous-phase reactions are investigated. Carbon is acidified with liquid and gas phase methods, using nitric and sulfuric acid, hydrogen peroxide and calcination in air at 300 and 400 °C. Modified carbons are characterized by nitrogen physisorption, scanning electron microscopy, point of zero charge measurements, Boehm titration, temperature-programmed desorption–mass spectrometry and X-ray photoelectron spectroscopy. Stability of acid functional groups under typical reaction conditions for biomass conversion is investigated by exposing carbons to hydrothermal treatment (i.e. hot liquid water). Special attention was devoted to elucidating the effect of the temperature (150–225 °C) and time of exposure (0–24 h) on the hydrothermal stability of different surface functional groups. Carbon modification by sulfuric acid generates strong acid sites in higher concentration, compared to carbon modified by nitric acid, calcination and hydrogen peroxide. In contrast to the other treatments, calcination at 400 °C increases carbon basicity. Although the concentrations of all surface acid sites decrease on the hydrothermal treatment, this effect is not uniform. Stability of acid sites with different strengths and their chemical nature are dependent on the modification method. Strong acid sites formed by sulfuric acid treatment show a much higher stability than those formed by the other acidification procedures. The H₂SO₄-treated material retains ca. 40% of strong acid sites even after exposure to hot liquid water at 200 °C for more than 4 h. Only such strong acid sites remain on the carbon surface after exposure to hot liquid water at 225 °C.

15/00121 Uncertainty in the uptake coefficient for HONO formation on soot and its impacts on concentrations of major chemical components in the Beijing–Tianjin–Hebei region

Tang, Y. *et al. Atmospheric Environment*, 2014, 84, 163–171.

The soot redox reaction with an uptake coefficient (γ) of 10^{-4} at night and the soot heterogeneous photochemistry with the γ formula of $J_{\text{NO}_2}/10$ in the daytime, where J_{NO_2} denotes the NO₂ photolysis frequency, were inserted into the WRF-Chem model to evaluate the effects of γ changes of several orders of magnitude on the concentrations of HONO, HO_x, O₃, NO₃, and NH₄⁺ in the Beijing–Tianjin–Hebei (BTH) region. Results demonstrated that the simulations in the BTH region support the redox mechanism at night and the heterogeneous photochemistry mechanism in the daytime for HONO formation, and suggested that the order of magnitude of γ is likely to be 10^{-4} . Minor increases in HONO, HO_x, O₃, NO₃, and NH₄⁺ were produced when γ was decreased to $\leq 10^{-5}$, whereas the concentrations of HONO and NO₃ were substantially overestimated in most cases when γ was increased to 10^{-3} . The soot surface area per unit volume of air showed a sharp decrease from $3 \times 10^3 \mu\text{m}^2 \text{cm}^{-3}$ near the ground to $6 \times 10^2 \mu\text{m}^2 \text{cm}^{-3}$ at ~200 m at night. The surface area fractions of soot, nitrate, and sulfate showed minor variations between day and night, although the surface areas of the major aerosol components at night were approximately three times those in the daytime.

05 NUCLEAR FUELS

Scientific, technical

15/00122 A cement degradation model for evaluating the evolution of retardation factors in radionuclide leaching models

Jacques, D. *et al. Applied Geochemistry*, 2014, 49, 143–158.

Near-surface cement-based disposal systems for hazardous materials such as radioactive waste will undergo chemical alterations due to interaction with the surrounding environment. One of the most relevant long-term geochemical alteration processes is decalcification or leaching of the cement phases by percolating water. Consequently, the cementitious components of the disposal system will evolve through different chemical degradation states, also altering physical material parameters such as porosity and bulk density and chemical parameter relevant to solute migration such as the solid–liquid partition coefficient or distribution ratio. This paper presents a novel approach in which geochemical modelling serves as a fundamental basis for

assessing the evolution of geochemical conditions within a cement-based near-surface disposal facility. On one hand, geochemical modelling is used to quantify uncertainties related to the infiltrating water composition and C–S–H degradation model, both of which allow for various conceptualizations of the evolution of retardation factor. On the other hand, the concept of mixed tank reactor is used to represent cement degradation within the entire disposal system. This paves the way to establish a link between the evolution of the geochemical conditions and the evolution of the retardation factor via the knowledge of amount of percolated water through the system. The usefulness of the approach is demonstrated via a number of case studies concerning leaching of radionuclides (¹⁴C and ⁹⁴Nb) from a cementitious near-surface disposal facility. The studies reveal that there is a large effect of the conceptualization on calculated fluxes from the disposal facility, depending on the type of radionuclide. A crucial factor is the amount of radionuclide mass present in the disposal system when large changes in the retardation factor occur, for instance, when different retardation factors exist in different chemical degradation states.

15/00123 Adsorptive removal of cesium using bio fuel extraction microalgal waste

Inoue, K. *et al. Journal of Hazardous Materials*, 2014, 271, 196–201.

An adsorption gel was prepared from microalgal waste after extracting biodiesel oil by a simple chemical treatment of crosslinking using concentrated sulfuric acid. The adsorbent exhibited notably high selectivity and adsorption capacity towards Cs⁺ over Na⁺ from aqueous solutions, within the pH range of slightly acidic to neutral. The adsorption followed Langmuir isotherm and the maximum adsorption capacity of the gel for Cs⁺ calculated from Langmuir model was found to be 1.36 mol kg⁻¹. Trace concentration of Cs⁺ ions present in aqueous streams was successfully separated from Na⁺ ions using a column packed with the adsorbent at pH 6.5. The adsorption capacity of the gel towards Cs⁺ in column operation was 0.13 mol kg⁻¹. Although the adsorbed Cs⁺ ions were easily eluted using 1 M hydrochloric acid solution, simple incineration is proposed as an alternative for the treatment of adsorbent loaded with radioactive Cs⁺ ions due to the combustible characteristics of this adsorbent.

15/00124 Analysis of a sustainable gas cooled fast breeder reactor concept

Kumar, A. *et al. Annals of Nuclear Energy*, 2014, 69, 252–259.

Analysis of a thorium-fuelled gas cooled fast breeder reactor (TGFBFR) concept has been done to demonstrate the self-sustainability, breeding capability, actinide recycling ability, and thorium fuel feasibility. Simultaneous use of ²³²Th and used fuel from light water reactor in the core has been considered. Results obtained confirm the core neutron spectrum dominates in an intermediate energy range (peak at 100 keV) similar to that seen in a fast breeder reactor. The conceptual design achieves a breeding ratio of 1.034 and an average fuel burn-up of 74.5 GWd/MTHM. TGFBFR concept is to address the eventual shortage of ²³⁵U and nuclear waste management issues. A mixture of thorium and uranium (²³²Th + ²³³U) is used as fuel and light water reactor used fuel is utilized as blanket, for the breeding of ²³⁹Pu. Initial feed of ²³³U has to be obtained from thorium based reactors; even though there are no thorium breeders to breed ²³³U a theoretical evaluation has been used to derive the data for the source of ²³³U. Reactor calculations have been performed with Monte Carlo radiation transport code, MCNP/MCNPX. It is determined that this reactor has to be fuelled once every 5 years assuming the design thermal power output as 445 MW. Detailed analysis of control rod worth has been performed and different reactivity coefficients have been evaluated as part of the safety analysis. The TGFBFR concept demonstrates the sustainability of thorium, viability of ²³³U as an alternate to ²³⁵U and an alternate use for light water reactor used fuel as a blanket for the production of plutonium.

15/00125 Bond graph representation of nuclear reactor point kinetics and nearly incompressible thermal hydraulics

Sosnovsky, E. and Forget, B. *Annals of Nuclear Energy*, 2014, 68, 15–29.

This work presents a simplified one-dimensional model for a pressurized water reactor core, suitable for very rapid transients like control rod ejection. The model is represented using the bond graph formalism, a technique for modelling engineering systems as combinations of connected elements. Bond graphs are a flexible way of presenting coupled physics problems by automating the computer science aspects of modelling and letting the modellers focus on the physics; they were introduced in earlier work. To help leverage the flexibility of bond graph representations of physical systems, a new bond graph processing code, BGSolver, is introduced. BGSolver has been developed by the authors over the past several years, and is now released as open-source software. A rapid rod ejection benchmark is solved with both BGSolver and RELAP5-3D; BGSolver obtained full convergence with a 5 ms time step, while RELAP5-3D required a 1 ms

time step, due to the fully coupled time integration that BGSolver employed, compared to an operator splitting-based time integrator of RELAP5-3D. BGSolver's time integrator demonstrated third-order convergence in time, a very desirable property. A single non-linear solve was used to obtain the steady state with BGSolver.

15/00126 Effects of fuel particle size distributions on neutron transport in stochastic media

Liang, C. *et al. Annals of Nuclear Energy*, 2014, 68, 146–156.

This paper presents a study of the fuel particle size distribution effects on neutron transport in three-dimensional stochastic media. Particle fuel is used in gas-cooled nuclear reactor designs and innovative light water reactor designs loaded with accident tolerant fuel. Due to the design requirements and fuel fabrication limits, the size of fuel particles may not be perfectly constant but instead follows a certain distribution. This brings a fundamental question to the radiation transport computation community: how does the fuel particle size distribution affect the neutron transport in particle fuel systems? To answer this question, size distribution effects and their physical interpretations are investigated by performing a series of neutron transport simulations at different fuel particle size distributions. An eigenvalue problem is simulated in a cylindrical container consisting of fissile fuel particles with five different size distributions: constant, uniform, power, exponential and Gaussian. A total of 15 parametric cases are constructed by altering the fissile particle volume packing fraction and its optical thickness, but keeping the mean chord length of the spherical fuel particle the same at different size distributions. The tallied effective multiplication factor (k_{eff}) and the spatial distribution of fission power density along axial and radial directions are compared between different size distributions. At low packing fraction and low optical thickness, the size distribution shows a noticeable effect on neutron transport. As high as 1.00% relative difference in k_{eff} and ~1.50% relative difference in peak fission power density are observed. As the packing fraction and optical thickness increase, the effect gradually dissipates. Neutron channelling between fuel particles is identified as the effect most responsible for the different neutronic results. Different size distributions result in the difference in the average number of fuel particles and their average size. As a result, different degrees of neutron channelling are produced. The size effect in realistic reactor unit cells is also studied and, from the predicted values of infinite multiplication factors, it is concluded that the fuel particle size distribution effects are not negligible.

15/00127 Examination of chemical and physical effects on sump screen clogging of containment materials used in Korean plants

Song, H. *et al. Annals of Nuclear Energy*, 2014, 69, 51–56.

This study investigated the chemical and physical effects on the mechanism of sump screen clogging of containment materials that are used in most Korean nuclear power plants, such as N-102, N-108 as coating materials, NUKON as insulating materials, and CLP and SLP as pipe materials. The experimental conditions for dissolution were pH 8.0 at 88 °C, and those for precipitation were pH 8.5 at 60 °C. The concentration of both dissolved and precipitated species were evaluated by using an inductively coupled plasma atomic emission spectroscopy and a particle size analyser, respectively. From the obtained dissolution/precipitation data, a unique two-step mechanism was derived for the sump screen clogging process. In the first step, the screen was sparsely covered with needle-shaped silicon fibre debris that formed from the insulating materials; in the second step, it was finally clogged with a few micrometre-sized metal hydroxide precipitate particles (predominantly calcium hydroxide) that were generated from the dissolved metal ions. Hence, it can be concluded that the silicon fibres deployed for the insulating materials should be replaced with alternative materials that generate no needle-shaped debris after breakage, and the gypsum component in the coating should be reduced as much as possible.

15/00128 FASTREACT – an efficient numerical framework for the solution of reactive transport problems

Trinchero, P. *et al. Applied Geochemistry*, 2014, 49, 159–167.

In the framework of safety assessment studies for geological disposal, large scale reactive transport models are powerful inter-disciplinary tools aiming at supporting regulatory decision making as well as providing input to repository engineering activities. Important aspects of these kinds of models are their often very large temporal and spatial modelling scales and the need to integrate different non-linear processes (e.g. mineral dissolution and precipitation, adsorption and desorption, microbial reactions and redox transformations). It turns out that these types of models may be computationally highly demanding. This study presents a Lagrangian-based framework, denoted as FASTREACT, which aims to solve multi-component reactive transport problems with a computationally efficient approach allowing complex modelling problems to be solved in large spatial and temporal scales. The tool has been applied to simulate radionuclide

migration in a synthetic heterogeneous transmissivity field and the results have been successfully compared with those obtained using a standard Eulerian approach. Finally, the same geochemical model has been coupled to an ensemble of realistic three-dimensional transport pathways to simulate the migration of a set of radionuclides from a hypothetical repository for spent nuclear fuel to the surface. The results of this modelling exercise, which includes key processes such as the exchange of mass between the conductive fractures and the matrix, show that FASTREACT can efficiently solve large-scale reactive transport models.

15/00129 Feasibility analysis of aggressive cooldown in OPR-1000 nuclear power plants

Kim, M. C. and Jerng, D. W. *Annals of Nuclear Energy*, 2014, 68, 89–95.

Aggressive cool-down is the action taken by main control room (MCR) operators to rapidly cool down and depressurize the reactor coolant system at the maximum allowed cooldown rate during a small break loss of coolant accident (SBLOCA) or a steam generator tube rupture accident with failure of high-pressure safety injection (HPSI) in a pressurized water reactor. The authors examined the feasibility of aggressive cool-down in OPR-1000 nuclear power plants by establishing success criteria based on experimental results and thermal-hydraulic code simulations, reviewing emergency operating procedures, and estimating the necessary time for MCR operators to initiate aggressive cool-down based on experimental results with licensed nuclear power plant operators. For an SBLOCA with a break size of 0.02 ft² combined with total failure of HPSI, it was found that aggressive cool-down can generally be performed successfully, but there is potential for failure to initiate aggressive cool-down in a timely manner. The authors discuss the potential effects of introducing the Ultimate Procedure on reducing the core damage potential. Detailed analysis and further discussion are necessary to reduce uncertainties associated with aggressive cool-down and its positive effect on the safety of nuclear power plants.

15/00130 Feasibility of shock attenuation by simple obstacles in mitigating severe accident explosive loads

Park, J.-W. and Kim, J.-S. *Annals of Nuclear Energy*, 2014, 70, 109–121.

The Fukushima nuclear power plant accident showed that explosions are possible in nuclear power plants and that creative safety features would be beneficial to preserve the integrity of vital components against such explosions. Based on this motivation, simple obstacles are suggested as a means to attenuate shock waves that may arise from severe accident explosions and the effectiveness is investigated by computations employing fully compressible viscous Navier–Stokes equations of the FLUENT code. Two- and three-dimensional computations for a shock tube filled with air are performed and the computed peak pressure and arrival time are validated against existing experimental data and analyses. Effects of structural shapes and rectangular rigid obstacles on shock attenuation in simple geometries are preliminarily analysed and the results show that the end wall peak pressure is reduced by about 18–30%. As a demonstration in a plant scale, a high pressure source of 0.2 m radius semicircle is positioned at the bottom centre of the two-dimensional hypothetical reactor cavity model (5.4 m by 9.4 m) and multiple rigid obstacles are positioned at the half-way between a reactor vessel and the pressure source. Incident circular shock wave is dispersed by the obstacles and the peak pressures at the reactor vessel bottom head centre and the 45° regions are reduced by about 35% and 50%, respectively. This study implies the feasibility of simple obstacles for attenuating shock waves from the explosions expected under nuclear power plant severe accidents.

15/00131 Fission gas release behaviour of a 103 GWd/t_{HM} fuel disc during a 1200 °C annealing test

Noirot, J. *et al. Journal of Nuclear Materials*, 2014, 446, (1–3), 163–171.

Within the Nuclear Fuel Industry Research (NFIR) programme, several fuel variants, in the form of thin circular discs, were irradiated in the Halden boiling water reactor (HBWR) to a range of burn-ups ~100 GWd/t_{HM}. The design of the assembly was similar to that used in other HBWR programmes: the assembly contained several rods with fuel discs sandwiched between Mo discs, which limited temperature gradients within the fuel discs. One such rod contained standard grain UO₂ discs (three-dimensional grain size = 18 μm) reaching a burn-up of 103 GWd/t_{HM}. After the irradiation, the gas release on rod puncturing was measured to be 2.9%. Detailed characterizations of one of these irradiated UO₂ discs, using electron probe microanalysis, scanning electron microscopy and secondary ion mass spectrometry, were performed in a CEA Cadarache hot laboratory. Examination revealed the high burn-up structure (HBS) formation throughout the whole of the disc, also the fission gas distribution within this HBS, with a very high proportion of the gas in the HBS bubbles. A sibling disc was submitted to a temperature transient up to 1200 °C in the out-of-pile annealing test device ‘Merarg’ at a relatively low temperature ramp rate (0.2 °C/s). In addition to the total gas release during this annealing

test, the release peaks throughout the temperature range were monitored. The fuel was then characterized with the same micro-analysis techniques as before the annealing test to investigate the effects of this test on the microstructure of the fuel and on the fission gases. This study provided valuable insights into fission gas localization and the release behaviour in UO_2 fuel with HBS.

15/00132 Fuel cycle modelling of open cycle thorium-fuelled nuclear energy systems

Ashley, S. F. *et al. Annals of Nuclear Energy*, 2014, 69, 314–330. This study determines the advantages, disadvantages, and viability of open cycle thorium–uranium-fuelled (Th–U-fuelled) nuclear energy systems. This has been done by assessing three such systems, each of which requires uranium enriched to $\sim 20\%$ ^{235}U , in comparison to a reference uranium-fuelled (U-fuelled) system over various performance indicators, spanning material flows, waste composition, economics, and proliferation resistance. The values of these indicators were determined using the UK National Nuclear Laboratory's fuel cycle modelling code ORION. This code required the results of lattice-physics calculations to model the neutronics of each nuclear energy system, and these were obtained using various nuclear reactor physics codes and burn-up routines. In summary, all three Th–U-fuelled nuclear energy systems required more separative work capacity than the equivalent benchmark U-fuelled system, with larger levelized fuel cycle costs and larger levelized cost of electricity. Although a reduction of $\sim 6\%$ in the required uranium ore per kWh was seen for one of the Th–U-fuelled systems compared to the reference U-fuelled system, the other two Th–U-fuelled systems required more uranium ore per kWh than the reference. Negligible advantages and disadvantages were observed for the amount and the properties of the spent nuclear fuel (SNF) generated by the systems considered. Two of the Th–U-fuelled systems showed some benefit in terms of proliferation resistance of the SNF generated. Overall, it appears that there is little merit in incorporating thorium into nuclear energy systems operating with open nuclear fuel cycles.

15/00133 Methodology for mechanical property testing of fuel cladding using an expanding plug wedge test

Jiang, H. and Wang, J.-A. J. *Journal of Nuclear Materials*, 2014, 446, (1–3), 27–37.

An analysis is presented to determine the stress–strain response of ring-shaped test specimen subjected to internal pressurization using a radially expanding plug. Previous work has been reviewed using this test method to determine the residual ductility of irradiated nuclear fuel cladding and highlight the role of several parameters on the distribution of stresses and the mode of failure. It is shown that bulging effect, which had previously not been accounted for, has a significant effect on the distribution of stresses and mode of failure. The new analysis provides guidelines for optimizing specimen geometry and loading conditions and a means for determining the hoop stress σ_θ in the ring-shaped test specimen using a scaling factor, χ -factor, to convert the ring load F_{ring} into hoop stress σ_θ , and is written as $\sigma_\theta = \chi F_{\text{ring}}/t$, where t is the clad thickness and l is the clad length. The predicted stress–strain curves were found to agree well with experimental results for alloy Zr-4 over 10% strain.

15/00134 New functionality of chalcogenide glasses for radiation sensing of nuclear wastes

Ailavajhala, M. S. *et al. Journal of Hazardous Materials*, 2014, 269, 68–73.

Data about γ -radiation-induced effects in $\text{Ge}_{40}\text{Se}_{60}$ chalcogenide thin films and radiation induced silver diffusion within these are presented. Blanket films and devices were created to study the structural changes, diffusion products, and device performance. Raman spectroscopy, X-ray diffraction, current vs voltage (I – V) and impedance measurements expound the behaviour of $\text{Ge}_{40}\text{Se}_{60}$ glass and silver diffusion within this glass under radiation. Raman study shows that there is a decrease in the area ratio between edge shared and corner shared structural units revealing structural reorganization occurring in the glasses as a result of gamma radiation. X-ray diffraction studies revealed that with sufficiently radiation dose it is also possible to create Ag_2Se in selenium-depleted systems. Oxidation of the Ge enriched chalcogenide backbone is confirmed through the electrical performance of the sensing elements based on these films. Combination of these structural and diffusion products influences the device performance. The I – V behaviour is characterized by increase in current and then stabilization as a function of radiation dose. Additionally, device modelling is also presented using Silvaco software and analytical methods to shed light on the device behaviour. This type of sensor design and material characterizations facilitate in improving the radiation sensing capabilities of silver containing chalcogenide glass thin films.

15/00135 Production of small uranium dioxide microspheres for cermet nuclear fuel using the internal gelation process

Hunt, R. D. *et al. Annals of Nuclear Energy*, 2014, 69, 139–143. The US National Aeronautics and Space Administration (NASA) is developing a uranium dioxide (UO_2)/tungsten cermet fuel for potential use as the nuclear cryogenic propulsion stage (NCPS). The first-generation NCPS is expected to be made from dense UO_2 microspheres with diameters between 75 and 150 μm . Previously, the internal gelation process and a hood-scale apparatus with a vibrating nozzle were used to form gel spheres, which became UO_2 kernels with diameters between 350 and 850 μm . For the NASA spheres, the vibrating nozzle was replaced with a custom designed, two-fluid nozzle to produce gel spheres in the desired smaller size range. This paper describes the operational methodology used to make 3 kg of uranium oxide (UO_x) microspheres.

15/00136 Radionuclides migration in the far field of geological repositories: a numerical example

Ferroni, L. and Miracapillo, C. *Energy Procedia*, 2014, 45, 691–700. Radioactive wastes can be classified according to their activities and their half-life period: high activity and/or long half-life may cause severe hazards to people and environment for thousands and thousands of years. For repositories of such dangerous wastes classified as category III by Italian law and as high level waste (HLW) by the International Atomic Energy Agency – the geological repository technology is the preferred technology. As one can imagine, most of the volume of these wastes are spent nuclear fuel and products of nuclear reprocessing plants. To permanently isolate HLW from the biosphere, the segregation of wastes in geological repositories, several hundred metres below the surface, is now under way in many countries where large, compact and impermeable geological formations, not exposed to the seismic risk, exist. Safety conditions associated with these repositories must be guaranteed also in the case that the secular contact of the waste canisters with the groundwater allows the radionuclides to migrate to the external environment. In the present article the first results of a numerical simulation made using Processing Modflow, one of the most complete groundwater simulation codes, are presented to assess the migration process of radionuclides in the far-field of a geological repository to study the influence of two important parameters, the distribution coefficient and the hydraulic gradient, on the numerical results.

15/00137 Redox processes in the safety case of deep geological repositories of radioactive wastes. Contribution of the European RECOsY Collaborative Project

Duro, L. *et al. Applied Geochemistry*, 2014, 49, 206–217. Redox processes influence key geochemical characteristics controlling radionuclide behaviour in the near and far field of a nuclear waste repository. A sound understanding of redox related processes is therefore of high importance for developing a safety case, the collection of scientific, technical, administrative and managerial arguments and evidence in support of the safety of a disposal facility. This paper presents the contribution of the specific research on redox processes achieved within the EURATOM Collaborative Project RECOsY (REdox phenomena COntrolling SYstems) to the safety case of nuclear waste disposal facilities. Main objectives of RECOsY were related to the improved understanding of redox phenomena controlling the long-term release or retention of radionuclides in nuclear waste disposal and providing tools to apply the results to performance assessment and the safety case. The research developed during the project covered aspects of the near-field and the far-field aspects of the repository, including studies relevant for the rock formations considered in Europe as suitable for hosting an underground repository for radioactive wastes. It is the intention of this paper to highlight in which way the results obtained from RECOsY can feed the scientific process understanding needed for the stepwise development of the safety case associated with deep geological disposal of radioactive wastes.

15/00138 Simulation of the behaviour of nuclear fuel under high burnup conditions

Soba, A. *et al. Annals of Nuclear Energy*, 2014, 70, 147–156. This paper summarizes all the models included in the latest version of the DIONISIO code related to the high burn-up scenario. Due to the extension of nuclear fuels permanence under irradiation, physical and chemical modifications are developed in the fuel material, especially in the external corona of the pellet. The codes devoted to simulation of the rod behaviour under irradiation need to introduce modifications and new models in order to describe those phenomena and be capable to predict the behaviour in all the range of a general pressurized water reactor. A complex group of subroutines has been included in the code in order to predict the radial distribution of power density, burn-up, concentration of diverse nuclides and porosity within the pellet. The behaviour of gadolinium as burnable poison also is modelled into the

code. The results of some of the simulations performed with DIONISIO are presented to show the good agreement with the data selected for the FUMEX I/II/III exercises, compiled in the Nuclear Energy Agency data bank.

15/00139 Stability of cemented dried water hyacinth used for biosorption of radionuclides under various circumstances

Saleh, H. M. *Journal of Nuclear Materials*, 2014, 446, (1–3), 124–133. This paper investigates the influence of frost attack and flooding conditions during disposal on the compressive strength, porosity and durability of cemented waste form contained dried and grinded water hyacinth. This plant was used as a phytoremediating agent to treat liquid waste simulate contaminated with radionuclides. The obtained results showed that an increase in the incorporated dry plants decreases the compressive strength and increases the porosity of the solidified waste form. Raising the number of freeze–thaw cycles was accompanied with noticeable increase in the mass-loss of tested specimens and unsteady trend of compressive strength and consequently the mechanical integrity. The presence and increase of immersion duration per turned positively the mass change and affect in different ways on the solidified waste form. Spectroscopic analyses such as infrared and X-ray as well as microscopic investigation were performed to evaluate the solidified waste form exposed to different undesirable climatic conditions during extending disposal durations. The use of Portland cement as a stabilizer for water hyacinth, following the phytoremediation process, achieves the requirements for durability and strength against the freeze–thaw cycles or flooding in different types of water during prolonged disposal.

15/00140 The digital mock-up system to simulate and evaluate the dismantling scenarios for decommissioning of a NPP

Jeong, K. S. *et al. Annals of Nuclear Energy*, 2014, 69, 238–245. This paper is to develop the digital mock-up system to simulate the dismantling scenarios for decommissioning of a nuclear power plants (NPP). Features of the digital mock-up system are kinematic simulation and human simulation of decommissioning scenarios of a NPP. The digital mock-up consists of major components, internals, support facilities and equipment. The digital mock-up system could evaluate and optimize the decommissioning scenarios of a NPP.

15/00141 The long-term effect of hydrogen on the UO₂ spent fuel stability under anoxic conditions: findings from the Cigar Lake Natural Analogue study

Bruno, J. and Spahiu, K. *Applied Geochemistry*, 2014, 49, 178–183. The present paradigm on UO₂ spent fuel stability under anoxic conditions assumes that the potential oxidative alteration of the matrix is suppressed in the presence of the hydrogen generated by the anoxic corrosion of iron by water. The observations from the Cigar Lake Natural Analogue project indicated the long-term stability of the uraninite ore under anoxic conditions and with substantial hydrogen generation. The radiolytic models developed in the analogue project have been used to test some of the hypothesis concerning the activation of hydrogen on the uranium(IV) oxide surface. Suggestions to pathways of radiolytic oxidant consumption by other processes than uranium dioxide or sulfide oxidation are presented. The stability of the ore body for billions of year indicates the presence of processes which neutralize radiolytic oxidants and one major factor may be the presence of dissolved hydrogen in the groundwaters contacting the ore body. The results from this test would indicate that hydrogen is activated on the surface of the Cigar Lake uraninites by alpha radiation consuming the generated radiolytic oxidants.

Economics, policy, supplies, forecasts

15/00142 A fuzzy-based reliability approach to evaluate basic events of fault tree analysis for nuclear power plant probabilistic safety assessment

Purba, J. H. *Annals of Nuclear Energy*, 2014, 70, 21–29. Fault tree analysis has been widely utilized as a tool for nuclear power plant probabilistic safety assessment. This analysis can be completed only if all basic events of the system fault tree have their quantitative failure rates or failure probabilities. However, it is difficult to obtain those failure data due to insufficient data, environment changing or new components. This study proposes a fuzzy-based reliability approach to evaluate basic events of system fault trees whose failure precise probability distributions of their lifetime to failures are not available. It applies the concept of failure possibilities to qualitatively evaluate basic events and the concept of fuzzy sets to quantitatively represent the corresponding failure possibilities. To demonstrate the

feasibility and the effectiveness of the proposed approach, the actual basic event failure probabilities collected from the operational experiences of the David-Besse design of the Babcock and Wilcox reactor protection system fault tree are used to benchmark the failure probabilities generated by the proposed approach. The results confirm that the proposed fuzzy-based reliability approach arises as a suitable alternative for the conventional probabilistic reliability approach when basic events do not have the corresponding quantitative historical failure data for determining their reliability characteristics. Hence, it overcomes the limitation of the conventional fault tree analysis for nuclear power plant probabilistic safety assessment.

15/00143 An approach for evaluating the integrity of fuel applied in innovative nuclear energy systems

Nakae, N. *et al. Journal of Nuclear Materials*, 2014, 446, (1–3), 1–9. One of the important issues in the study of innovative nuclear energy systems is evaluating the integrity of fuel applied in these systems. An approach for evaluating the integrity of the fuel is discussed here based on the procedure currently used in the integrity evaluation of fast reactor fuel. The fuel failure modes determining fuel life time were reviewed and fuel integrity was analysed and compared with the failure criteria. Metal and nitride fuels with austenitic and ferritic stainless steel (SS) cladding tubes were examined in this study. For the purpose of representative irradiation behaviour analyses of the fuel for innovative nuclear energy systems, the correlations of the cladding characteristics were modelled based on well-known characteristics of austenitic modified 316 SS (PNC316), ferritic–martensitic steel and oxide dispersion strengthened steel. The analysis showed that the fuel lifetime is limited by channel fracture which is a non-ductile type (brittle) failure associated with a high level of irradiation-induced swelling in the case of austenitic steel cladding. In case of ferritic steel, on the other hand, the fuel lifetime is controlled by cladding creep rupture. The lifetime evaluated here is limited to 200 GW d/t, which is lower than the target burn-up value of 500 GW d/t. One of the possible measures to extend the lifetime may be reducing the fuel smeared density and ventilating fission gas in the plenum for metal fuel and by reducing the maximum cladding temperature from 650 to 600 °C for both metal and nitride fuel.

15/00144 An evaluation of the dismantling technologies for decommissioning of nuclear power plants

Jeong, K. S. *et al. Annals of Nuclear Energy*, 2014, 69, 62–64. This paper proposes an evaluation method on the dismantling technologies for decommissioning of nuclear power plants. The parameters of evaluation are performance impacts, site-specific impacts, safety impacts, and cost impacts. The evaluation method for cutting the tubes in a steam generator of nuclear power plants was applied, using four technologies: waterjet technology, shear technology, plasma technology and band saw technology. The shear technology was evaluated as an optimal cutting technology for the tubes. This evaluation method could be also applied for other decommissioning technologies as well as dismantling technologies. This evaluation method could settle the overall cost effectiveness and safety of selecting the options and strategy of decommissioning.

15/00145 Analysis of advanced European nuclear fuel cycle scenarios including transmutation and economic estimates

Rodríguez, I. M. *et al. Annals of Nuclear Energy*, 2014, 70, 240–247. Four European fuel cycle scenarios involving transmutation options (in coherence with PATEROS and CP-ESFR European Union projects) have been addressed from a point of view of resources utilization and economic estimates. Scenarios include: (i) the current fleet using light water reactor (LWR) technology and open fuel cycle, (ii) full replacement of the initial fleet with fast reactors (FR) burning U–Pu MOX fuel, (iii) closed fuel cycle with minor actinide (MA) transmutation in a fraction of the FR fleet and (iv) closed fuel cycle with MA transmutation in dedicated accelerator-driven systems (ADS). All scenarios consider an intermediate period of GEN-III+ LWR deployment and they extend for 200 years, looking for long-term equilibrium mass flow achievement. The simulations were made using the TR_EVOL code, capable to assess the management of the nuclear mass streams in the scenario as well as economics for the estimation of the levelized cost of electricity (LCOE) and other costs. Results reveal that all scenarios are feasible according to nuclear resources demand (natural and depleted U, and Pu). Additionally, it was found, as expected, that the FR scenario reduces considerably the Pu inventory in repositories compared to the reference scenario. The elimination of the LWR MA legacy requires a maximum of 55% fraction (i.e. a peak value of 44 FR units) of the FR fleet dedicated to transmutation (MA in MOX fuel, homogeneous transmutation) or an average of 28 units of ADS plants (i.e. a peak value of 51 ADS units). Regarding the economic analysis, the main usefulness of the provided economic results is for relative comparison of scenarios and breakdown of LCOE contributors rather than provision of absolute values, as technological readiness levels are low for most of the advanced fuel cycle stages. The

obtained estimations show an increase of LCOE – averaged over the whole period – with respect to the reference open cycle scenario of 20% for Pu management scenario and around 35% for both transmutation scenarios. The main contribution to LCOE is the capital costs of new facilities, quantified between 60% and 69% depending on the scenario. An uncertainty analysis is provided around assumed low and high values of processes and technologies.

15/00146 Assessment of the evolution of the redox conditions in a low and intermediate level nuclear waste repository (SFR1, Sweden)

Duro, L. *et al. Applied Geochemistry*, 2014, 49, 192–205.

The evaluation of the redox conditions in an intermediate and low level radioactive waste repository such as SFR1 (Sweden) is of high relevance in the assessment of its future performance. The SFR1 repository contains heterogeneous types of wastes, of different activity levels and with very different materials, both in the waste itself and as immobilization matrices and packaging. The level of complexity also applies to the different reactivity of the materials, so that an assessment of the uncertainties in the study of how the redox conditions would evolve must consider different processes, materials and parameters. This paper provides an assessment of the evolution of the redox conditions in the SFR1. The approach followed is based on the evaluation of the evolution of the redox conditions and the reducing capacity in 15 individual waste package types, selected as being representative of most of the different waste package types present or planned to be deposited in the SFR1. The model considers different geochemical processes of redox relevance in the system. The assessment of the redox evolution of the different vaults of the repository is obtained by combining the results of the modelled individual waste package types. According to the model results, corrosion of the steel-based material present in the repository keeps the system under reducing conditions for long time periods. The simulations have considered both the presence and the absence of microbial activity. In the initial step after the repository closure, the microbial mediated oxidation of organic matter rapidly causes the depletion of oxygen in the system. The system is afterwards kept under reducing conditions, and hydrogen is generated due to the anoxic corrosion of steel. The times for exhaustion of the steel contained in the vaults vary from 5 to more than 60 ky in the different vaults, depending on the amount and the surface area of steel. After the complete corrosion of steel, the system still keeps a high reducing capacity, due to the magnetite formed as steel corrosion product. The redox potential in the vaults is calculated to evolve from oxidizing at very short times, due the initial oxygen content, to very reducing at times shorter than 5 years after repository closure. The redox potential imposed by the anoxic corrosion of steel and hydrogen production is on the order of -0.75 V at pH 12.5. In case of assuming that the system responds to the Fe(III)/magnetite system, and considering the uncertainty in the pH due to the degradation of the concrete barriers, the redox potential would be in the range -0.7 to -0.01 V. A Monte-Carlo probabilistic analysis on the rate of corrosion of steel shows that the reducing capacity of the system provided by magnetite is not exhausted at the end of the assessment period, even assuming the highest corrosion rates for steel. Simulations assuming presence of oxic water due to glacial melting, intruding the system 60 ky after repository closure, indicate that magnetite is progressively oxidized, forming Fe(III) oxides. The time at which magnetite is completely oxidized varies depending on the amount of steel initially present in the waste package. The behaviour of Np, Pu, Tc and Se under the conditions foreseen for this repository is discussed.

15/00147 Atmospheric dispersion modeling and radiological safety analysis for a hypothetical accident of Ghana Research Reactor-1 (GHARR-1)

Muswema, J. L. *et al. Annals of Nuclear Energy*, 2014, 68, 239–246.

Atmospheric dispersion modelling and radiological safety analysis were performed for a postulated accident scenario of the generic low-enriched uranium (LEU) Ghana Research Reactor-1 (GHARR-1) core. The source term was generated from an inventory of peak radioisotope activities released by using the isotope generation code MCNPX. The health physics code, HotSpot, was used to perform the atmospheric transport modelling which was then applied to calculate the total effective dose and how it would be distributed to human organs as a function of distance downwind. All accident scenarios were selected from the GHARR-1 safety analysis report, assuming that the activities were released to the atmosphere after a design basis accident. The adopted methodology was the use of predominant site-specific meteorological data and dispersion modelling theories to analyse the incident of a hypothetical release to the environment of some selected radionuclides from the site and evaluate to what extent such a release may have radiological effects on the public. The results indicate that all the values of effective dose obtained, with the maximum of

2.62×10^{-2} mSv at 110 m from the reactor, were far below the regulatory limits, making the use of the reactor safe, even in the event of severe accident scenario.

15/00148 Factors controlling radiocaesium distribution in river sediments: field and laboratory studies after the Fukushima Dai-ichi Nuclear Power Plant accident

Fan, Q. *et al. Applied Geochemistry*, 2014, 48, 93–103.

This study used laboratorial estimations and determined the distribution coefficient (K_d) of ^{137}Cs in river sediments sampled from the Abukuma and the Kuchibuto rivers to investigate the particle size dependence of radiocaesium's distribution. Results show that the K_d patterns of ^{137}Cs (particle size-dependence of K_d) were not only related to the particle size of large particles (low clay mineral content) but also to the clay mineral content of small particles (high clay mineral content) and particularly cation concentration in aqueous phase. By contrast, the K_d patterns of stable Cs (^{133}Cs) exhibited no obvious particle size dependence. Adsorption species of Cs that was added to the river sediments at various particle sizes was almost the same at the molecular scale as determined by the extended X-ray absorption fine structure. The findings indicate that river sediments have high fixation ability to ^{137}Cs . Nevertheless, adsorbed ^{137}Cs can be extracted from sediments in the water phase when salinity becomes high, such as that in seawater. The distribution patterns of ^{137}Cs at various particle sizes can slowly down the equilibrium of the adsorption of ^{137}Cs during the transportation of river sediments, and then the behaviour of ^{137}Cs should eventually be similar to that of stable Cs in the river system. Therefore, the particle size of sediments is an important factor in the distribution of radiocaesium at the early stage of its deposition. In the end, radiocaesium adsorbed on the sediments will be equilibrated with the stable Cs during its transportation in the river system. Controlling factors such as the mineralogy of sediments could possibly make the distribution patterns of radiocaesium similar to that of stable Cs in the long run.

15/00149 Geological disposal of nuclear waste: II. From laboratory data to the safety analysis – addressing societal concerns

Grambow, B. and Bretesché, S. *Applied Geochemistry*, 2014, 49, 247–258.

After more than 30 years of international research and development, there is a broad technical consensus that geologic disposal of highly-radioactive waste will provide for the safety of humankind and the environment, now, and far into the future. Safety analyses have demonstrated that the risk, as measured by exposure to radiation, will be of little consequence. Still, there is not yet an operating geologic repository for highly radioactive waste, and there remains substantial public concern about the long-term safety of geologic disposal. In these two linked papers, the authors argue for a stronger connection between scientific data and the safety analysis, particularly in the context of societal expectations. In this paper, the authors assess the meaning of the technical results and derived models (from part I, entitled 'Nuclear waste disposal: I. Laboratory simulation of repository properties') for the determination of the long-term safety of a repository. They consider issues of model validity and their credibility in the context of a much broader historical, epistemological and societal context. Safety analysis is treated in its social and temporal dimensions. This perspective provides new insights into the societal dimension of scenarios and risk analysis. Surprisingly, there is certainly no direct link between increased scientific understanding and a public position for or against different strategies of nuclear waste disposal. This is not due to the public being poorly informed, but rather due to cultural cognition of expertise and historical and cultural perception of hazards to regions selected to host a geologic repository. The societal and cultural dimension does not diminish the role of science, as scientific results become even more important in distinguishing between the conflicting views of the risk of geologic disposal of nuclear waste.

15/00150 Hydrogen uptake and diffusion in Callovo-Oxfordian clay rock for nuclear waste disposal technology

Bardelli, F. *et al. Applied Geochemistry*, 2014, 49, 168–177.

The Callovo-Oxfordian clay-rich rock formation is currently considered as host rock barrier in the French geological repository facility for radioactive waste (Meuse/Haute-Marne). After the closure of the facility, hydrogen gas is expected to develop mainly from anaerobic corrosion of steel containers and other iron-containing structures. Gas pressure build-up could impact the safety of the repository. It is therefore important to acquire in-depth knowledge on the interaction between hydrogen gas and surrounding clay rock in terms of uptake ability and diffusion. Hydrogen uptake capacity was evaluated on dried clay rock samples: (i) at 20 K, to allow for hydrogen liquefaction and determine the maximal H_2 uptake of the clay, and (ii) at typical pressure and temperature conditions expected to develop in the repository (up to 363 K and a hydrogen pressure of 40–60 bar). H_2 absorption on the dried raw Callovo-Oxfordian start to saturate at

about 30–40 bar, and the average adsorption above 40 bar is about 0.1% in weight. Quasi-elastic neutron scattering spectroscopy was used to study the diffusion mechanism of hydrogen gas in the clay rock at the microscopic scale and to determine hydrogen self-diffusion coefficients in the dry samples in the temperature range 25–300 K. Neutron data suggested that hydrogen diffuses in the dry clay rock according to Fick's law. The findings reported in this work can help to better understand the behaviour of H₂ in clay rock samples.

15/00151 Issues of operating systems usage for nuclear power plants

Andryushin, A. *et al. Annals of Nuclear Energy*, 2014, 70, 87–89.
This paper discusses the problems of selecting and justifying operational software, especially operating systems, for nuclear power plants. Operating systems must meet the requirements of international organizations (e.g. IEAE, IEC, ISO). The most important standards (IEC 61513:2011, ISO/IEC 23360-1:2006 and ISO/IEC 27032:2012) were analysed. Furthermore, the issue of conformance one of the most widespread operating system Linux to the requirements of the standards was analysed. Based on the analysis of the documentation, compliance with the ISO/IEC 23360:2006 and functionality of the Linux operating system, a conclusion can be made on insufficient justification for its use in nuclear power plants instrumentation and control (systems in accordance with IEC) without substantial and laborious verification, validation, certification and technical support. A subject of the technical-and-economical assessment is a possibility of either modifying the Linux operating system for further installation as software for the instrumentation and control systems of nuclear power plants or the need to purchase specific software adapted for use within nuclear power plant systems.

15/00152 Molecular structures and thermodynamic properties of monohydrated gaseous iodine compounds: modelling for severe accident simulation

Sudolská, M. *et al. Journal of Nuclear Materials*, 2014, 446, (1–3), 73–80.

Monohydrated complexes of iodine species (I, I₂, HI, and HOI) have been studied by correlated ab initio calculations. The standard enthalpies of formation, Gibbs free energy and the temperature dependence of the heat capacities at constant pressure were calculated. The values obtained have been implemented in ASTEC nuclear accident simulation software to check the thermodynamic stability of hydrated iodine compounds in the reactor coolant system and in the nuclear containment building of a pressurized water reactor during a severe accident. It can be concluded that iodine complexes are thermodynamically unstable by means of positive Gibbs free energies and would be represented by trace level concentrations in severe accident conditions; thus it is well justified to only consider pure iodine species and not hydrated forms.

15/00153 Nuclear waste disposal: I. Laboratory simulation of repository properties

Grambow, B. *et al. Applied Geochemistry*, 2014, 49, 237–246.

After more than 30 years of research and development, there is a broad technical consensus that geologic disposal will provide for the safety of humankind, now and far into the future. Safety analyses have demonstrated that the risk, measured as the exposure to radiation, will be of little consequence. Still, there is not yet an operating geologic repository for highly radioactive waste, and there remains substantial public concern about the long-term safety of geologic disposal. In the two linked papers, the authors argue for a stronger connection between the scientific data (in this paper) and the safety analysis, particularly in the context of societal expectations (in part II, entitled 'Geological disposal of nuclear waste: II. From laboratory data to the safety analysis – addressing societal concerns'). In this paper, the authors use new experimental data on the properties of clay formations simulating geological disposal conditions to illustrate how one can understand the ability of clay to isolate radionuclides. The data include percolation tests on various intact clay-rock cores with different calcite contents. For the first time, hydrodynamic parameters (anion and cation accessible porosities, permeability, dispersion and diffusion coefficients), as well as retention parameters (sorption behaviour of iodine, caesium) and materials interaction parameters (glass dissolution rates, etc.) have been obtained for a series of clay-rock samples of varying mineralogy. Increased calcite content leads to lower permeability and porosity, but the difference between anion and cation accessible porosity diminished. The data confirm very slow radionuclide migration, and a direct extrapolation to repository geometry yields isolation times, for a 70 m clay-rock formation, of many hundreds of thousands of years, even for the most mobile radionuclides such as iodine-129 and chlorine 36 and complete retention for the more radiotoxic, less mobile radionuclides such as the actinides or caesium-137. In order to assess the meaning of the technical results and derived models for long-term safety, paper II addresses model validity and credibility not only from a technical perspective, but in a much broader

historical, epistemological and societal context. Safety analysis is treated in its social and temporal dimensions. This approach provides new insights into the societal dimension of scenarios and risk, and it shows that there is certainly no direct link between increased scientific understanding and a public position for or against different strategies of nuclear waste disposal.

15/00154 Obtaining isochrones from pollution signals in a fluvial sediment record: a case study in a uranium-polluted floodplain of the Ploučnice River, Czech Republic

Grygar, T. M. *et al. Applied Geochemistry*, 2014, 48, 1–15.

Uranium mining and processing in the watershed of the Ploučnice River in the Czech Republic during a well-defined time interval (1969–1989) allowed for a study of pollutant fates in sediments of a meandering river that is otherwise in a nearly natural state. A considerable part of the primary pollution is present in hotspots in the floodplain 10–15 km downstream from the mining district. One of the hotspots was characterized using geoinformatic, geophysical and geochemical means. The floodplain geomorphology and architecture and river channel dynamics were studied to develop an understanding of the formation of the hotspot and evaluate further movement of pollutants in the river system. Local background functions (with Rb or Ti as a predictor) and local enrichment factors (LEFs) were obtained for Ba, Ni, Pb, U and Zn concentrations in unpolluted sediments from the deeper strata of the active floodplain, an abandoned floodplain and an ancient terrace. The most recent (2013) overbank fines in the study area are still considerably enriched in Ni, U and Zn (LEF 3, 6 and 8, respectively), and thus pollution by heavy metals several kilometres downstream of the hotspots continuously increases even though the primary source of pollution was terminated more than 20 years ago. The onset of the primary pollution (the base of the polluted strata) is hence clearly identified in the distal floodplain sediments as persistent and a potentially isochronous pollution signal in the fluvial record, whereas a secondary pollution signal overwrites the expected 'primary pollution climax' and 'pollution improvement' signals. That inertia of the fluvial system can also be expected in other river systems with both laterally and vertically deposited sediments. The Ploučnice case study allowed for further elaboration of the concept of local enrichment factors in pollution assessment of fluvial sediments, which efficiently reduces the grain-size effects (the impact of hydraulic sorting) and hence allows for reconstruction of the pollution history.

15/00155 Safety analysis and optimization of the core fuel reloading for the Moroccan TRIGA mark-II reactor

Nacir, B. *et al. Annals of Nuclear Energy*, 2014, 70, 312–316.

The Moroccan TRIGA mark II reactor core is loaded with 8.5% in weight of uranium standard fuel elements. Additional fresh fuel elements must periodically be added to the core in order to remedy the observed low power and to return to the initial reactivity excess at the end of cycle. Fuel elements of 12%-uranium are available to relatively improve the short fuel lifetime associated with standard TRIGA elements. These elements have the same dimensions as standards elements, but with different uranium weight. The objective in this study is to demonstrate that the Moroccan TRIGA reactor could safely operate, around 2 MW power, with new configurations containing these 12% fuel elements. For this purpose, different safety related thermal-hydraulic parameters have been calculated in order to ensure that the safety margins are largely respected. Therefore, the PARET model for this TRIGA reactor that was previously developed and combined with the MCNP transport code in order to calculate the three-dimensional temperature distribution in the core and all the most important parameters like the axial distribution of departure from nucleate boiling ratio across the hottest channel. The most important conclusion is that the 12% fuel elements utilization will have no influence on the safety of the reactor while working around 2 MW power especially for configurations based on insertions in C and D-rings.

15/00156 Safety evaluation of the modified auxiliary feedwater system for the Chinese improved PWR

Tong, L. L. *et al. Annals of Nuclear Energy*, 2014, 70, 169–174.

The Chinese National Nuclear Safety Administration (NNSA) has issued the general technique requirements of the modification actions for nuclear power plants (NPPs). The enlargement of the tank volume of the auxiliary feedwater system (ASG) is one of the modification actions to enhance the safety margin for the Chinese improved pressurized water reactor (PWR) NPPs. Therefore, it is necessary to evaluate the tank volume of ASG can supply enough cooling water to the secondary side of the steam generators under the transient accidents, to maintain the reactor under safety situation. Typical accident sequences, such as the category II accidents of the loss of feedwater (LOFW) with no loss of offsite power (no-LOOP) and the category IV accidents of the feedwater line break (FWLB) with no-LOOP and the FWLB combined with LOOP, are selected to analyse the minimum flow rate and volume for ASG, based on the RCC-P

requirements, based on the model of the typical improved generation II 1000 MWe NPP, built by using the mechanical safety analytical code. The auxiliary feedwater flow rates of 5, 10, 15 and 25 m³/h to each steam generator (SG) for the LOFW with no-LOOP are investigated by analysing the transient progress, and the results show that the minimum flow rate is 25 m³/h. FWLB transients with different flow rates of 30, 35 and 45 m³/h are also analysed to show that 45 m³/h is the minimum flow rate considering a safety margin. The minimum volume of the auxiliary feedwater tank is 713 m³ for the LOFW, 723 m³ for the FWLB with no-LOOP and 799 m³ for the FWLB combined with LOOP. Therefore, considering the safety margin, the minimum auxiliary feedwater flow rate necessary to prevent bulk boiling in the reactor coolant system is 45 m³/h for each unbroken SG, and a 900-m³ volume of auxiliary feedwater tank can satisfy the RCC-P requirements for the improved PWR NPPs, to give more time to take mitigation measurements.

15/00157 The influence of stable element inventory on the migration of radionuclides in the vicinity of a high level nuclear waste repository exemplified for ⁵⁹Ni

Pfingsten, W. *Applied Geochemistry*, 2014, 49, 103–115.
A generic modelling approach has been used to estimate the influence of the stable inventory, i.e. stable isotopes in a radioactive waste repository on the migration of radionuclides from waste canisters into the surrounding bentonite or Opalinus Clay. The model radionuclide chosen was bivalent ⁵⁹Ni(II); the stable isotopes Ni(II), Fe(II), Mn(II), Zn(II) and Cu(II) are considered to be competitive for the same sorption sites on bentonite or Opalinus Clay. A simplified one-dimensional modelling approach in space was used for reactive transport calculations using the MCOTAC code incorporating the 2SPNE SC/CE sorption model. Calculated ⁵⁹Ni(II) breakthrough curves in bentonite and Opalinus Clay are compared to estimates of the influences of the individual competing metals present in the porewaters. Generally, faster migration, i.e. a reduced sorption, for ⁵⁹Ni(II) was calculated – up to two orders of magnitude in arrival time at specified locations in the bentonite or Opalinus Clay. This influence is a maximum for highest specified stable isotope concentrations. Fe, Zn and Mn have approximately the same effect on the migration of ⁵⁹Ni(II); Cu has the potential for a much stronger effect. However, their individual effects at reducing the retardation of ⁵⁹Ni(II) through sorption competition do not sum up linearly. In the various scenarios calculated, an upper limit for the reduction of the retardation of ⁵⁹Ni(II) has been assessed for the combined sorption competition influence of all the stable isotopes. Although the calculated scenarios include several simplifications, they cover a wide range of combinations of sorption competition effects of stable isotopes present in a high-level waste repository on the migration of radioactive ⁵⁹Ni(II). More detailed scenario calculations would be possible if a more detailed ‘geochemical inventory’ of radionuclides and stable isotopes were to become available. Nevertheless, upper limits for the effects of sorption competition of bivalent stable isotopes on the migration of ⁵⁹Ni in the vicinity of a high-level nuclear waste repository were assessed.

15/00158 Uncertainty analysis using Beta-Bayesian approach in nuclear safety code validation

Deng, C. *et al. Annals of Nuclear Energy*, 2014, 70, 103–108.
Since best-estimate plus uncertainty analysis was approved by the US Nuclear Regulatory Commission for nuclear reactor safety evaluation, several uncertainty assessment methods have been proposed and applied in the framework of best-estimate code validation in nuclear industry. Among them, the Wilks’ method and Bayesian approach are the two most popular statistical methods for uncertainty quantification. This study explores the inherent relation between the two methods using the beta distribution function as the prior in the Bayesian analysis. Subsequently, the Wilks’ method can be considered as a special case of beta-Bayesian approach, equivalent to the conservative case with Wallis’ ‘pessimistic’ prior in the Bayesian analysis. However, the results do depend on the choice of the pessimistic prior function forms. The analysis of mean and variance through beta-Bayesian approach provides insight into the Wilks’ 95/95 results with different orders. It indicates that the 95/95 results of Wilks’ method become more accurate and more precise with the increasing of the order. Furthermore, Bayesian updating process is well demonstrated in the code validation practice. The selection of updating prior can make use of the current experience of the code failure and success statistics, so as to effectively predict further needed number of numerical simulations to reach the 95/95 criterion.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

15/00159 3E (energy, environmental, and economy) evaluation and assessment to an innovative dual-gas polygeneration system

Yi, Q. *et al. Energy*, 2014, 66, 285–294.
To resolve problems surrounding simultaneous CO₂ conversion and coke oven gas (COG) utilization, a novel system combining a dual-gas of coal gasified gas (CGG) and COG with the technology of CO₂ recycling into a single gasifier and reforming unit is proposed. 3E performance (energy, environmental, and economic) analysis showed that this novel system renders unnecessary the traditional water–gas shift process, and realizes the conversion and utilization of CH₄ and CO₂ that would otherwise be directly discharged into the air. Under a weak carbon mitigation policy, the economics of co-producing low-carbon fuels and electricity from a dual-gas of CGG and COG are promising. The ‘dual-gas’ technology is a potentially viable option for clean coal and its efficient use in the co-production of low-carbon fuels and electricity in areas possessing COG, natural gas or other unconventional natural gas resources.

15/00160 A GIS (geographic information system)-based optimization model for estimating the electricity generation of the rooftop PV (photovoltaic) system

Hong, T. *et al. Energy*, 2014, 65, 190–199.
The global photovoltaic (PV) generation market has been rapidly growing. In the introduction of a PV system, the electricity generation efficiency of the PV system depends on regional factors and on-site installation factors. It has a significant effect on the returns on investment. Therefore, this study conducted a sensitivity analysis on how the impact factors of the rooftop PV system affect its electricity generation. Based on the results of the sensitivity analysis, this study aimed to ultimately develop a geographic information system (GIS)-based optimization model for estimating the electricity generation of the rooftop PV system. Several impact factors were used in the sensitivity analysis. The result of this study showed that there were 1.12-, 1.62- and 1.37-fold differences in the annual electricity generation of the rooftop PV system in South Korea due to the regional factor, the azimuth of the installed panel, and the slope of the installed panel, respectively. Using a GIS-based optimization model, the final decision-maker could easily and accurately estimate the electricity generation of the rooftop PV system in a preliminary feasibility study.

15/00161 A multi-level control architecture for master-slave organized microgrids with power electronic interfaces

Cai, N. and Mitra, J. *Electric Power Systems Research*, 2014, 109, 8–19.
In this work, a comprehensive multi-level control architecture was described for master–slave organized microgrids with power electronic interfaced distributed generators. A new multi-agent system power balance control strategy was presented that can accomplish exact power balance in three sweeps, regardless of system size. Unlike most of the power balance algorithm proposed in the literature, this algorithm achieves power balance in a non-iterative way; therefore, it does not encounter any convergence problem. Meanwhile, the information is designed to be transmitted in a parallel manner, which provides superior speed advantage to satisfy real-time control compared with the methods available in the literature. An economic dispatch algorithm suitable for the proposed decentralized multi-agent system was also presented and demonstrated for microgrids that are amenable to optimal dispatch. By limited communications with neighbours, generator agents are able to optimize total generation cost in a non-increasing direction. This algorithm is robust and fault-tolerant that if one generator agent fails, only the generation at that single node is not optimized; while other agents can still collaborate to optimize total generation cost. In the presence of markets, the quadratic generation cost function can be replaced by bids, and the associated objective function, such as social welfare function, can also be optimized by the proposed multi-agent system. The performance of the proposed strategy was demonstrated on several test systems. Its benefits, both in terms of speed as well as robustness in tracking time-varying loads, were demonstrated.

15/00162 Aggregation of microgrids with DC system

Majumder, R. *Electric Power Systems Research*, 2014, 108, 134–143.
The aspiration of this paper is to scrutinize the feasibility of DC system connecting multiple AC microgrids for improved system reliability. In this paper, first multiple microgrids connected through a back-to-back connection (with better power flow control as well as frequency isolation) is contemplated. Each of the microgrids can operate in island or grid connected mode. The control and power flow management of the multiple microgrids system are first depicted with a common DC link capacitor. As second step, the DC capacitor is dispersed among the converter terminals as separate converter DC capacitor. As final step, the back to back converters are assumed to be far from each other and connected through DC cables. This result in a multi terminal medium voltage DC system connected to multiple AC microgrids. The active power, reactive power and output current capability of each converter terminal depends on the corresponding microgrid operating mode, DG output, local load demand, etc. A DC system connecting multiple AC microgrids (with VSC interfaced DGs and ability to operate in island) bestows a test bench for studying the possibility smaller grids for higher reliability and better power flow management. The control schemes, generalized guidelines for such integrated system are proposed based on currently available standards, equipment, devices, system solutions and market requirements.

15/00163 An efficient harmony search with new pitch adjustment for dynamic economic dispatch

Niu, Q. *et al. Energy*, 2014, 65, 25–43.
A simple yet efficient harmony search (HS) method with a new pitch adjustment rule (NPAHS) is proposed for dynamic economic dispatch (DED) of electrical power systems, a large-scale non-linear real-time optimization problem imposed by a number of complex constraints. The new pitch adjustment rule is based on the perturbation information and the mean value of the harmony memory, which is simple to implement and helps to enhance solution quality and convergence speed. A new constraint handling technique is also developed to effectively handle various constraints in the DED problem, and the violation of ramp rate limits between the first and last scheduling intervals that is often ignored by existing approaches for DED problems is effectively eliminated. To validate the effectiveness, the NPAHS is first tested on 10 popular benchmark functions with 100 dimensions, in comparison with four HS variants and five state-of-the-art evolutionary algorithms. Then, NPAHS is used to solve three 24-h DED systems with 5, 15 and 54 units, which consider the valve point effects, transmission loss, emission and prohibited operating zones. Simulation results on all these systems show the scalability and superiority of the proposed NPAHS on various large-scale problems.

15/00164 Design and operation of a tri-generation system for a station in China

Zhao, X. *et al. Energy Conversion and Management*, 2014, 80, 391–397.
Tri-generation usually refers to the simultaneous production of power, heating and cooling. Tri-generation can be regarded as a high-efficiency technology, provided that a large proportion of the energy rejected by the prime mover is used. In this paper, the design and operation of a tri-generation system for a railway station was investigated. The system is composed of the internal combustion engine, absorption heat pump, heat exchanger and other facilities. The system was built and operated in 2011, and the energy efficiency level was analysed. The results indicated that the calculated maximum comprehensive energy efficiency was 94.94% in the winter and 84.33% in the summer; with the calculated maximum exergy efficiency is 38.01% in the winter and 36.01% in the summer. The primary energy saving of the system was 32.2% in the winter and 4.9% in the summer. The system could therefore be regarded as high efficiency tri-generation. The recovered year of the increased investment was 5.47 years compared with the reference system. These results could serve as a reference for designing or evaluating tri-generation systems.

15/00165 Dynamic performance assessment of a micro-trigeneration system with a desiccant-based air handling unit in Southern Italy climatic conditions

Angrisani, G. *et al. Energy Conversion and Management*, 2014, 80, 188–201.
In this work, a system consisting of a small-scale trigeneration system, in which a heat-led microcogenerator interacts with a desiccant-based cooling system, equipped with a silica-gel desiccant wheel, is analysed. The system provides the air-conditioning service to a lecture room during summer and winter periods and, over the whole year, thermal energy for domestic hot water production to a nearby multifamily house. Electricity from the cogenerator is used to drive the electric chiller, the auxiliaries as well as further electric appliances of the lecture room. This trigeneration system is compared with a reference system, equipped with a conventional air handling unit, based on cooling dehumidification for summer air conditioning. Electricity to power the electric chiller, the auxiliaries, as well as electric appliances

is drawn from the grid. Thermal energy for winter space heating, air post-heating during summer and domestic hot water purposes is provided by a natural gas boiler. Experimental tests, as well as data derived from manufacturers, are used to implement a model of both systems. Simulations were then performed by means of TRNSYS software to compare their thermo-economic performance. A sensitivity analysis has been performed, to analyse the effect of the share of cogenerated electricity consumed on-site. The analysis shows encouraging results, given the Italian energy context for the small-scale trigeneration system, in terms of primary energy consumption and equivalent carbon dioxide emissions reductions, with maximum values of 7.70% and 15.3%, respectively; on the other hand, it is difficult to achieve a reasonably short payback period for the system, even if it accesses all the support mechanisms introduced by Italian legislation for small-scale gas-fuelled trigeneration systems and a very high amount of cogenerated electricity is used on-site.

15/00166 Influence of cable losses on the economic analysis of efficient and sustainable electrical equipment

Lobão, J. A. *et al. Energy*, 2014, 65, 145–151.
Increasing energy needs are accompanied by environmental responsibilities, since nowadays electricity companies operate in a competitive and sustainable energy framework. In this context, any proposal for action on energy efficiency becomes important for consumers to minimize operational costs. In electrical installations, electricity consumption can be decreased by reducing losses in the cables, associated with the overall efficiency of the equipment, allowing a better use of the installed power. The losses must be analysed in conjunction with all loads that contribute to the currents in the sections of an electrical installation. When replacing equipment in output distribution boxes with more efficient ones, the current in those sections is reduced in association with the decrease in power losses. This decrease, often forgotten, is taken into account in this work for the economic analysis of efficiency and sustainable electrical equipment. This paper presents a new software application that compares and chooses the best investment in the acquisition of electrical equipment. The results presented confirm that the net present value is superior when the losses are included, and may even switch from negative to positive. The importance of the application of software in real situations was also demonstrated and validated with experimental results, making it possible to analyse and choose effective solutions from the point of view of economic profitability, making energy use more efficient and sustainable. The analysis of energy efficiency in industrial systems should include the whole life cycle and all the components and losses of the system for a proper assessment.

15/00167 Multi-objective optimized management of electrical energy storage systems in an islanded network with renewable energy sources under different design scenarios

Ippolito, M. G. *et al. Energy*, 2014, 64, 648–662.
This paper considers strategies for the design and the optimized management of electrical energy storage (EES) systems, for an existing islanded distribution network supplying the island of Pantelleria, Italy in the Mediterranean Sea. In the paper the authors have drawn interesting conclusions through the application of an efficient multi-objective optimization algorithm, the NSGA-II, minimizing the energy losses in the grid, the total electricity generation cost and the greenhouse gas emissions. The results obtained for different installation scenarios of the EES are presented and discussed, putting into evidence the technical, environmental and economic benefits of using EES as well as the technical issues connected to their installation into an existing distribution network. The paper describes in details the second part of a feasibility study about the transition from a 'fuel-based' traditional centralized electrical system to an active and smart 'renewables-based' electrical distribution system.

15/00168 Numerical analysis of a unidirectional axial turbine for twin turbine configuration

Pereiras, B. *et al. Applied Ocean Research*, 2014, 47, 1–8.
One of the most developed technologies in ocean energy is the oscillating water column (OWC) concept. It is well known that the efficiency of the device is closely related to the efficiency of the power-take-off (PTO) which is usually a turbine. Traditionally, self-rectifying turbines are the most widely considered for working in an OWC because unidirectional turbines require a system of valves to rectify the flow. However, another option has been recently proposed: 'twin turbine' configuration. This paper is focused on the performance of the turbines used in this configuration. A computational fluid dynamics model has been created in Fluent software and validated with data from the bibliography. This model has been used to analyse the flow field of the turbine when working in both operation modes: direct and reverse. Flow angles and loss distribution have been analysed and interesting conclusions can be extracted. The efficiency of the twin turbine configuration has been calculated from the results of the

numerical model. The calculations have been made paying attention to the effect of the torque and the flow rate of the turbine which is working in reverse mode. The results obtained are the core of this work. Once the flow field has been analysed, changes in the turbine geometry are proposed in order to improve the efficiency of the whole system by increasing the blockage made by the turbine in reverse mode. These changes were focused on the solidity of the rotor and guide vanes.

15/00169 Operational limits of a three level neutral point clamped converter used for controlling a hybrid energy storage system

Etcheberria, A. *et al. Energy Conversion and Management*, 2014, 79, 97–103.

This work analyses the use of a three-level neutral point clamped (3LNPC) converter to control the power flow of a hybrid energy storage systems (HESS) and at the same time interconnect it with the common AC bus of a microgrid. There is presently not any storage technology capable of offering a high-energy storage capacity, a high-power capacity and a fast response at the same time. Therefore, the necessity of hybridizing more than one storage technology is a widely accepted idea in order to satisfy the mentioned requirements. This work shows how the operational limits of the 3LNPC converter can be calculated and integrated in a control structure to facilitate an optimal use of the HESS according to the rules fixed by the user.

15/00170 Optimal management of the automatic generation control service in smart user grids including electric vehicles and distributed resources

Battistelli, C. and Conejo, A. J. *Electric Power Systems Research*, 2014, 111, 22–31.

This paper presents an analysis and systemization of automatic generation control (AGC) in distribution networks (DNs) with high penetration of distributed resources, including electric vehicles (EVs). A methodology is developed that allows designing the AGC service at the distribution level, and an optimization model is proposed to assess the potential of AGC provision from EVs according to an objective of optimal economic management. A realistic case study is considered to analyse the proposed approach, and to illustrate both the potential of the methodology and the effectiveness of the optimization model. Results show that the proposed methodology represents a flexible tool that any system operator could use for the operational planning and the management of ancillary services such as AGC with EVs.

15/00171 Optimizing storages for transmission system operation

Eickmann, J. *et al. Energy Procedia*, 2014, 46, 13–21.

A growing amount of congestions is expected for future operation of electrical transmission grids in Europe. Within this context, storage can be used to assist transmission system operators in daily operation and to avoid costly redispatch measures. In this paper, a research methodology to evaluate impact and interdependencies between market operation of storages and participation in redispatch measures is presented. Furthermore, a methodology for the evaluation of benefits by storages solely administrated by transmission system operators is introduced. The methods are evaluated in a case study for the German electricity system in the year 2020. The expansion of energy storage in Germany leads to slight changes in energy generation and a small reduction of the overall generation costs. The participation of storage in redispatch causes reduced amounts of redispatch energy and costs. The benefit of storages solely operated by a transmission system operator is traceable, especially for long-planning horizons, but does not decisively exceed the generation cost savings caused by market-operated storages.

15/00172 Reconfigurable multiphase multi GW LCL DC hub with high security and redundancy

Lin, W.-X. and Jovic, D. *Electric Power Systems Research*, 2014, 110, 104–112.

Future DC transmission grids may include a central DC hub which will be connecting numerous DC lines and transferring multi GW power. The LCL DC hub is a multiport high power DC/DC converter that incorporates an inner LCL circuit to interconnect DC systems with different DC voltages through DC/AC ports. The LCL DC hub has an intrinsic attribute to limit the propagation of DC faults such that DC fault at one DC transmission line will not bring down the DC voltage or cause DC over current on other DC lines. As the operating security of the hub is of top concern, this paper proposes a reconfigurable multiphase method to avoid a common failure mode. The $n-1$ redundancy and expandability using multi-phase approach are analysed and compared with other methods. A fast, on-line phase reconfiguration and phase replacing control of the DC hub are proposed and verified, enabling the hub to continue operating under single-phase faults. Common mode current of the LCL DC hub is analysed to provide guidelines on structure and operation of the ports. It is

concluded that four-phase topology, possibly with a redundant fifth phase might offer best overall performance and with high redundancy/security required for large DC grids.

15/00173 Short-term scheduling of thermal power systems using hybrid gradient based modified teaching-learning optimizer with black hole algorithm

Azizipanah-Abarghooee, R. *et al. Electric Power Systems Research*, 2014, 108, 16–34.

A challenge facing electric power system operators is how to manage optimally the power generating units over a scheduling horizon of 1 day considering all of the practical equality, inequality and dynamic constraints. These constraints are comprised of load plus transmission losses balance, valve-point effects (VPEs), prohibited operating zones (POZs), multi-fuel options, line flow constraints, operating reserve (OR) and minimum on/off time. This paper develops a new efficient gradient-based modified teaching-learning-based optimization combined with black hole (GMTLBO-BH) to solve the short-term thermal generation scheduling (STGS) problem. The non-linear, non-smooth and non-convex components caused by losses, VPEs, multi-fuel options, line flow limit, ramp rate, POZs and minimum on/off time are modelled in the problem. The complexity of the problem is increased when the ORs and high dimensional test systems are considered. In this regard, the GMTLBO-BH uses the concepts from the combination of evolutionary algorithms, that is, modified teaching-learning-based optimization and black hole, utilizing the new self-adaptive wavelet mutation operator to escape from local optima, and classical optimization algorithms, i.e. gradient-based method. The suggested method is tested on three small and large cases. The performance of GMTLBO-BH was compared with the other optimization algorithms and concluded that this technique is more robust, more efficient and faster in acquiring better quality solutions with noteworthy difference in the total operation costs. All in all, the proposed approach can be a good candidate for real-time and real-size applications. Future works will concentrate on considering the emission objective function besides the cost function and solving the multi-objective short-term scheduling of hydrothermal power systems.

15/00174 Smart DER control for minimizing power losses in distribution feeders

Di Fazio, A. R. *et al. Electric Power Systems Research*, 2014, 109, 71–79.

In this paper, a new reactive power control scheme for distributed energy resources (DERs) has been proposed so as to minimize the power losses in a smart distribution grid. The classical DER reactive power control scheme has been enriched by an on-line optimization strategy, whose strong points are: to keep the classical structure of a DER control system, to use only local measurements of voltage and current at the point of common coupling, to account for the changes of the operating conditions of the distribution system, to limit on-line data exchange with the high voltage/medium voltage substation to the only case of significant changes of the distribution system structure and to avoid any data exchange with other DERs. The only drawback is related to the modelling approximations that are introduced in presence of multiple DERs and that cause inaccuracies in the output of the optimization strategy. Numerical simulation results have evidenced the improvements of the performance by adopting the proposed optimization strategy, which proved to give suboptimal results very close to the optimal ones.

15/00175 Technical-economic analysis of including wind farms and HFC to solve hybrid TNEM-RPM problem in the deregulated environment

Shayeghi, H. and Hashemi, Y. *Energy Conversion and Management*, 2014, 80, 477–490.

This paper addresses a mathematical model for solving transmission network expansion management (TNEM) associated with reactive power management (RPM) in the presence of double-fed induction generator (DFIG) variable speed wind turbine and hybrid flow controller (HFC). According to this plan, the reactive power capability of DFIG wind turbine is gained and the constraints of deliverable power are derived for each operation point. Strong control capability of the HFC with controlling bus voltage and line power flow offers a great potential for solving many of the problems facing electric utilities. For a precise steady-state analysis of HFC, the injection model is considered which it is an adaptive model in steady-state analysis. The main goals of the proposed management strategy are to minimize investment cost, real power loss cost in transmission lines and voltage deviation and maximize voltage stability index and social benefit at the same time. A three-stage scheme has been developed for solving hybrid TNEM-RPM problem. In the beginning of the plan, it is assumed that all the reactive demands are acquired from local sources and an optimal transmission plan is specified. After transmission lines are constructed, in the second step, reactive power sources will be allocated to weak buses. In order to assess reliability of the system, EENS

criterion is used. Due to multi-objective nature of the proposed management method, an improved non-dominated sorting genetic algorithm-II (NSGA-II) style is applied for an optimization procedure. Also, a decision making method based on fuzzy decision making is used for finding the best compromise solution from the set of Pareto-solution obtained by NSGA-II technique. In a real power system, Azarbaijan regional power system of Iran, comparative analysis of the results obtained from previous management methods and the proposed approach is represented.

Economics, policy, supplies, forecasts

15/00176 A full demand response model in co-optimized energy and reserve market

Liu, G. and Tomovic, K. *Electric Power Systems Research*, 2014, 111, 62–70.

It has been widely accepted that demand response will play an important role in reliable and economic operation of future power systems and electricity markets. Demand response can not only influence the prices in the energy market by demand shifting, but also participate in the reserve market. This study proposes a full model of demand response in which demand flexibility is fully utilized by price responsive shiftable demand bids in energy market as well as spinning reserve bids in reserve market. A co-optimized day-ahead energy and spinning reserve market is proposed to minimize the expected net cost under all credible system states, i.e. expected total cost of operation minus total benefit of demand, and solved by mixed integer linear programming. Numerical simulation results on the IEEE reliability test system show effectiveness of this model. Compared to conventional demand shifting bids, the proposed full demand response model can further reduce committed capacity from generators, starting up and shutting down of units and the overall system operating costs.

15/00177 A new demand response scheme for electricity retailers

Mahmoudi, N. *et al. Electric Power Systems Research*, 2014, 108, 144–152.

A new demand response (DR) scheme from the retailers' point of view is presented in this paper. The proposed DR scheme allows a retailer to decide how to buy DR from aggregators and consumers. Various long-term and real-time DR agreements are proposed, where they are considered as energy resources of retailers in addition to the commonly used providers. These innovative agreements include pool-order options, spike-order options, forward DR contracts and reward-based DR. A stochastic energy procurement problem for retailers is formulated, in which pool prices and customers' participation in the reward-based DR are uncertain variables. The feasibility of the problem is assessed using a realistic case of the Queensland jurisdiction within the Australian National Electricity Market. The outcomes indicate the usefulness of the given DR scheme for retailers, particularly for the conservative ones.

15/00178 Biochar as a sustainable electrode material for electricity production in microbial fuel cells

Huggins, T. *et al. Bioresource Technology*, 2014, 157, 114–119.

Wood-based biochars were used as microbial fuel cell electrodes to significantly reduce cost and carbon footprint. The biochar was made using forestry residue (BCc) and compressed milling residue (BCp). Side-by-side comparison show the specific area of BCp ($469.9 \text{ m}^2 \text{ g}^{-1}$) and BCc ($428.6 \text{ cm}^2 \text{ g}^{-1}$) is lower than granular activated carbon (GAC) ($1247.8 \text{ m}^2 \text{ g}^{-1}$) but higher than graphite granule (GG) ($0.44 \text{ m}^2 \text{ g}^{-1}$). Both biochars showed power outputs of $532 \pm 18 \text{ mW m}^{-2}$ (BCp) and $457 \pm 20 \text{ mW m}^{-2}$ (BCc), comparable with GAC ($674 \pm 10 \text{ mW m}^{-2}$) and GG ($566 \pm 5 \text{ mW m}^{-2}$). However, lower material expenses made their power output cost $17\text{--}35 \text{ US\$ W}^{-1}$, 90% cheaper than GAC ($402 \text{ US\$ W}^{-1}$) or GG ($392 \text{ US\$ W}^{-1}$). Biochar from waste also reduced the energy and carbon footprint associated with electrode manufacturing and the disposal of which could have additional agronomic benefits.

15/00179 Differential electricity pricing and energy efficiency in South Africa

Kohler, M. *Energy*, 2014, 64, 524–532.

By international standards the economy of South Africa is extremely energy intensive with only a few countries having higher intensities. South Africa's primary energy use per unit of gross domestic product is amongst the highest in the world. The high energy and electricity intensity of the economy partly reflects South Africa's resource endowments (in particular the abundance of coal) but is also a function of the historical underpricing of coal and electricity by the authorities. South African mining and industrial electricity efficiency is particularly concerning and considerably lower than the global average.

This paper sets out to fill a significant gap in the South African energy literature by highlighting the importance of incorporating electricity demand factors as part of the country's energy policy and electricity planning horizon. The paper focuses its attention on modelling the electricity consumption of South Africa's industrial and mining sectors given these account for the largest proportion of electricity demand. A differential electricity pricing policy which targets electricity intensive industrial and mining activities (as practised in China since 2004) is viewed by the author to be a superior policy to blanket electricity price increases administered by authorities in an effort to encourage electricity savings and improve energy efficiency in South Africa.

15/00180 Dynamic Granger-causal networks of electricity spot prices: a novel approach to market integration

Castagneto-Gissey, G. *et al. Energy Economics*, 2014, 44, 422–432.

This study uses network theory to analyse the interactions of a representative sample of 13 European Union (EU) electricity spot prices during the period 2007–2012. A total of 7651 dynamic multivariate networks were constructed, where the nodes correspond to different EU countries and the links weight the Granger-causality between the variations of the respective electricity prices. Global connectivity was then characterized by the system's density, or the total quantity of causal interactivity sustained by the network system, which informs about the occurrence of abnormal changes in connectivity. A large peak lasting from October 2011 to April 2012 was reported, where the graph's density over-basal jump reached a magnitude of 2.4 times, suggesting an improved degree of connectivity of electricity markets during this period. By applying the Markov regime-switching model on the network density it was found that this change coincides with the implementation of the European Commission's Third Energy Package. At the local level, the in-strength values quantifying the dependence of the electricity price variation of an EU country on other countries, validate the reliability of this technique by verifying historical events such as the occurrence of interconnectors commissioning and market coupling. On the path to full market integration, market networks should be periodically monitored. The model, which is able to create a time-varying network describing the evolving influences between the European electricity prices, was able to detect important changes in market integration and can be considered a suitable and promising approach for this task.

15/00181 Electric vehicle models for evaluating the security of supply

Bremermann, L. E. *et al. Electric Power Systems Research*, 2014, 111, 32–39.

The future large-scale deployment of electric vehicles (EV) will not only have impact on load growth, but also create opportunities for the electricity sector. Generally, the current methods for security of supply long-term evaluation do not include this new type of load. While the electric components of the generating systems are usually modelled by the Markov process, this paper presents, as its major contribution, an EV model based on the non-homogeneous Poisson process (NHPP), which has been developed in order to better represent the motorized citizen mobility and the EV opportunity to release spinning reserve to electric systems. The simulation procedure lies in combining both Poisson and Markov processes into a sequential Monte Carlo simulation (SMCS) to measure the impact of EV when evaluating the adequacy of generating systems. This evaluation is divided into two complementary concepts: static reserve (generating capacity reserve) and operating capacity reserve. The proposed models are analysed using a modified version of the IEEE RTS-96 including renewable sources. The use of the NHPP model in SMCS allows the analysis of the EV impact in the same time basis of the generating unit transition and makes it possible to monitor the battery state of charge of each vehicle as well as the ramp of EV load events. On the other hand, a previous work shows that the PP model clusters the EV arrivals in an hourly basis leading the EV charging to start at the same time, providing pessimistic risk indices. Regarding the charging strategies, the simulations performed revealed that it is very important to define an adequate strategy in order to mitigate the impact of EV load in the generating systems. Summarizing, the direct charging strategy penalizes the peak hour, following the usual habit of the citizens. The valley charging mode seems to be a suitable strategy up to a certain level of EV penetration. For high levels, the peak load could be moved to the valley period. Under proper standardization and regulation, controlled charging strategies may allow the EV contribution to the OCR through the action of postponing the battery charging, releasing generating capacity to meet the system uncertainties. Regarding the ramp analysis, some events could provoke significant impact, highlighting the necessity of analysing these situations, assessing namely whether the flexibility of the generating systems meets the EV ramp requirements. This situation will be exploited in future studies which consider higher EV penetration levels. Finally, the standardization and implementation of communication infrastructures that make possible to control

charging strategies are essential. In fact, the security of supply will depend not only on the EV penetration level, but also on the way that this type of load will be managed.

15/00182 Electricity market models and RES integration: the Greek case

Simoglou, C. K. *et al. Energy Policy*, 2014, 67, 531–542.

This paper presents an extensive analysis of the Greek electricity market for the next 7-year period (2014–2020) based on an hour-by-hour simulation considering five different renewable energy sources (RES) technologies, namely wind, PV, small hydro, biomass and combined heat and power with emphasis on PV integration. The impact of RES penetration on the electricity market operation is evaluated under two different models regarding the organization of the Greek wholesale day-ahead electricity market: a mandatory power pool for year 2014 (current market design) and a power exchange for the period 2015–2020 (target model). An integrated software tool is used for the simulation of the current and the future day-ahead market clearing algorithm of the Greek wholesale electricity market. Simulation results indicate the impact of the anticipated large-scale RES integration, in conjunction with each market model, on specific indicators of the Greek electricity market in the long-term.

15/00183 Electricity prices forecasting by a hybrid evolutionary-adaptive methodology

Osório, G. J. *et al. Energy Conversion and Management*, 2014, 80, 363–373.

With the restructuring of the electricity sector in recent years, and the increased variability and uncertainty associated with electricity market prices, it has become necessary to develop forecasting tools with enhanced capabilities to support the decisions of market players in a competitive environment. Hence, this paper proposes a new hybrid evolutionary-adaptive methodology for electricity prices forecasting in the short-term, i.e. between 24 and 168 h ahead, successfully combining mutual information, wavelet transform, evolutionary particle swarm optimization, and the adaptive neuro-fuzzy inference system. In order to determine the accuracy, competence and proficiency of the proposed methodology, results from real-world case studies using real data are presented, together with a thorough comparison considering the results obtained with previously reported forecasting tools. Not only is the accuracy an important factor, but also the computational burden is relevant in a comparative study. The results show that it is possible to reduce the uncertainty associated with electricity market prices prediction without using any exogenous data, just the historical values, thus requiring just a few seconds of computation time.

15/00184 Electricity-generation mix considering energy security and carbon emission mitigation: case of Korea and Mongolia

Ryu, H. *et al. Energy*, 2014, 64, 1071–1079.

To compare electricity-generation fuel mixes in two countries with multiple energy policy goals and unique circumstances, the authors looked at three scenarios reflecting the carbon emissions mitigation targets, differences in energy security levels, and electricity-generating costs of each nation. Korea and Mongolia show clear differences in electricity-generation structure related to import dependency, the potential of renewable energy, and threats to energy security. These variations lead to different decisions on the power-generation fuel mix plan. Use of fossil fuel resources in Korea results in carbon dioxide emissions and energy insecurity, while in Mongolia carbon emissions, also from fossil fuels, and energy insecurity are separate concerns as Mongolia domestically operates coal-fired power plants and imports electricity. Policies targeting two objectives, carbon emissions mitigation and energy security improvement, show complementarity in Korea as fossil fuels are replaced by renewables or nuclear power, but represent trade-offs in Mongolia as emissions mitigation and improved energy security cannot be achieved with one strategy. In conclusion, national plans to achieve two goals differ by country. In Korea, the appropriate portion of nuclear energy is the determining policy factor. In Mongolia, carbon capture and storage is the clear alternative for mitigating carbon emissions despite large renewables potential.

15/00185 Ensemble re-forecasting methods for enhanced power load prediction

Kaur, A. *et al. Energy Conversion and Management*, 2014, 80, 582–590.

Electric load forecasting is a key element for management and operation of the electric grid. This study introduces ensemble re-forecast methods that take an initial forecast and produce a better prediction by extracting information from the structured errors. The models in the ensemble rely upon the real-time information obtained from load measurements and estimates over a state-wide domain. The weights in the ensemble are optimized in three different ways based on global, hourly, and weekly performance of the models. The proposed methodology is applied to predict hour-ahead market (HAM) and day-ahead market (DAM) load for California Independent System

Operator (CAISO) and Electric Reliability Council of Texas (ERCOT) respectively. Proposed models showed consistent performance enhancements for all the cases. HAM predictions show an improvement of 47% and 36% in terms of mean absolute percentage error over the forecasts provided by CAISO and ERCOT. For DAM, the improvements are 34% for CAISO and 47% for ERCOT. Temporal analysis comparing the internal forecast produced by the ISOs and re-forecasts shows significant improvement during off-peak hours and small improvement for on-peak hours. Results validate the potential of the proposed methodology to enhance the forecast accuracy, independent of load profile or forecast horizon.

15/00186 Envisioning a renewable electricity future for the United States

Mai, T. *et al. Energy*, 2014, 65, 374–386.

This paper presents high renewable electricity penetration scenarios in the USA using detailed capacity expansion modelling that is designed to properly account for the variability and uncertainty of wind and solar resources. The scenarios focus solely on the electricity system, an important sector within the larger energy sector, and demonstrate long-term visions of a US power system where renewable technologies, including biomass, geothermal, hydropower, solar, and wind, contribute 80% of 2050 annual electricity, including 49–55% from wind and solar photovoltaic generation. This study presents the integration challenges of achieving this high penetration and characterize the options to increase grid flexibility to manage variability. Four high renewable pathways are modelled and demonstrate the robustness and diversity of renewable options. The authors estimate 69–82% annual greenhouse gas emission reductions and 3–30% incremental electricity price increases associated with reaching 80%-by-2050 renewable electricity relative to reference scenarios. This paper affirms and strengthens similar analysis from the Renewable Electricity Futures study by using an improved model and updated data to better reflect investment and dispatch decisions under current outlooks for the US electricity sector.

15/00187 Estimating the economic value of residential electricity use in the Republic of Korea using contingent valuation

Lim, K.-M. *et al. Energy*, 2014, 64, 601–606.

This study attempts to estimate the economic value of residential electricity use in the Republic of Korea. According to micro-economic theory, the economic benefit of residential electricity consumed is the sum of the actual residential electricity price and the additional willingness to pay (WTP) for the consumption. The authors apply the dichotomous choice contingent valuation method to assess the additional WTP. Moreover, the spike model is applied to dealing with the zero WTP responses. The results show that the mean additional WTP for the residential electricity is estimated to be KRW15.38 (US\$0.01) per kWh. Given that the average price of residential electricity is KRW103.40 (\$0.10) per kWh at the time of the survey, the economic benefit that ensues from the residential electricity consumption is computed as KRW118.78 (\$0.11) per kWh. This information can be beneficially utilized in conducting an economic feasibility study for a new project related to residential electricity supply service.

15/00188 Estimation of demand response to energy price signals in energy consumption behaviour in Beijing, China

He, Y. X. *et al. Energy Conversion and Management*, 2014, 80, 429–435.

The energy price system in Beijing has not fully exploited customers' price elasticity, and has a negative impact on achieving the goals of energy saving. This paper analyses the response behaviours of different customers to typical energy prices. As for electricity self-elasticity, the range of the primary, secondary, tertiary industry and residents are -0.026 to -0.033 , -0.045 to -0.059 , -0.035 to -0.047 and -0.024 to -0.032 , respectively. As regards self-elasticity on coal, the range of the primary, secondary, tertiary industry and residents are -0.030 to -0.037 , -0.066 to -0.093 , -0.055 to -0.072 and -0.034 to -0.051 , respectively. The self-elasticities on oil and natural gas are very weak. As for cross-elasticity, when consuming electricity and oil, customers mainly focus on the prices of natural gas, which are 0.185 and 0.112. When consuming coal and natural gas, customers are concerned about the electricity prices, and their cross-elasticities are 0.03 and 0.36, respectively. The estimation of demand response to energy price signals in energy consumption behaviours can provide a decision support for formulating rational energy price policies.

15/00189 Evaluation of supply interruption costs for residential sector in Serbia

Nahman, J. *et al. Electric Power Systems Research*, 2014, 110, 39–44.

The evaluation of the costs associated with the interruptions of the supply with the electrical energy is very important in planning of power system operation and structure using the cost-benefit approach. Many detailed studies have been performed in the past in order to evaluate the supply curtailment effects with particular concern about residential

customers. The consequences of supply curtailments have been assessed using surveys asking the customers to perceive the costs to households for a fixed scenario regarding the season of the year, day and time of interruption occurrence. This paper makes an attempt to enhance this analysis by treating the household activities as flows of events overlapping by chance with supply interruptions. Household activities have been modelled separately for various seasons of the year during weekdays and holidays in order to evaluate the interruption consequences in all possible circumstances. These data have been then used to determine the expected customer interruption costs on annual base.

15/00190 Experimental and data collection methods for a large-scale smart grid deployment: methods and first results
Rhodes, J. D. *et al. Energy*, 2014, 65, 462–471.

This paper has two objectives: (1) to describe the experimental and data collection methods for a large-scale smart grid deployment in Austin, Texas, USA, and (2) to provide results based on those data. As of October 2012, the test bed was comprised of 250 homes concentrated in a single neighbourhood all built after 2007 and 160 homes distributed throughout Austin with ages ranging from 10 to 92 years old. This experiment includes 200 electric monitoring systems (15-s resolution), 211 electric monitoring systems (1-min), 182 gas meters (2-cubic ft), and 51 water meters (1 gallon) and many of the monitored homes also have energy audits and homeowner surveys. The test bed also includes 185 rooftop photovoltaic installations and 50 electric vehicles in the same neighbourhood. Data streams were automated and gathered at a supercomputing facility at UT-Austin yielding 250 GB (2.95×10^9 records) of data in the first year. This paper describes the baseline study and monitoring methods, characterizes the study participants, and provides some first results about residential energy use. These results include a negative correlation between energy use and knowledge about energy as well as a possible positive correlation between energy use and some rebates.

15/00191 Influence of wind power on hourly electricity prices and GHG (greenhouse gas) emissions: evidence that congestion matters from Ontario zonal data

Amor, M. B. *et al. Energy*, 2014, 66, 458–469.

With the growing share of wind production, understanding its impacts on electricity price and greenhouse gas (GHG) emissions becomes increasingly relevant, especially to design better wind-supporting policies. Internal grid congestion is usually not taken into account when assessing the price impact of fluctuating wind output. Using 2006–2011 hourly data from Ontario, Canada, the impact of wind output, both on price level and marginal GHG emissions, greatly differs depending on the congestion level. Indeed, from an average of 3.3% price reduction when wind production doubles, the reduction jumps to 5.5% during uncongested hours, but is only 0.8% when congestion prevails. Similarly, avoided GHG emissions due to wind are estimated to 331.93 kg/MWh using all data, while for uncongested and congested hours, estimates are respectively 283.49 and 393.68 kg/MWh. These empirical estimates, being based on 2006–2011 Ontario data, cannot be generalized to other contexts. The main contribution of this paper is to underscore the importance of congestion in assessing the price and GHG impacts of wind. The authors also contribute by developing an approach to create clusters of data according to the congestion status and location. Finally, different approaches were compared to estimate avoided GHG emissions.

15/00192 Joint energy and reserve markets: current implementations and modeling trends

González, P. *et al. Electric Power Systems Research*, 2014, 109, 101–111.

The continuous penetration of intermittent technologies is gradually reinforcing the technical and economic importance of electricity ancillary services, which are responsible for guaranteeing the reliability and security of the power systems. Generation companies', regulating entities, system operators and other institutions (such as researchers on these fields) are more and more concerned on using market models to forecast most relevant outcomes for particular markets (such as energy and reserves cleared quantities and prices), under different simulation scenarios (such as costs or demand) and under different markets structures (such as more competitive or more oligopolistic). This paper reviews most energy and reserve markets implementations (mainly focusing on reserve types and dispatching methods), and discusses different approaches to model them. A theoretical equilibrium model for energy and reserve markets is also proposed.

15/00193 Lessons from international experience for China's microgrid demonstration program

Romankiewicz, J. *et al. Energy Policy*, 2014, 67, 198–208.

Microgrids can provide an avenue for increasing the amount of distributed generation and delivery of electricity, where control is more dispersed and quality of service is locally tailored to end-use

requirements, with applications from military bases to campuses to commercial office buildings. Many studies have been done to date on microgrid technology and operations, but fewer studies exist on demonstration programmes and commercial microgrid development. As China prepares to launch the largest microgrid demonstration programme in the world, the authors review progress made by demonstration programs across Europe, Asia, and the Americas as well as microgrid benefits and barriers. Through case studies, the differences in experience for microgrids developed under the auspices of a government-sponsored demonstration programme versus those that were commercially developed are highlighted. Finally, recommendations oriented towards creating a successful microgrid demonstration programme are provided.

15/00194 Modeling the daily electricity price volatility with realized measures

Frömmel, M. *et al. Energy Economics*, 2014, 44, 492–502.

This study uses realized GARCH-type models to estimate the daily price volatility in the EPEX power markets. The model specifications extract the volatility-related information from realized measures, which improves the in-sample fit of the data. More importantly, evidence on the out-of-sample predictability reinforces the value of the specifications, as the forecast quality is improved over the benchmark EGARCH model under eight conventional criteria. In particular, it is shown that the benefit of including intraday range as a realized measure is more substantial than realized variance. All the key findings are robust under rolling-window and recursive estimation schemes, Gaussian and skewed *t*-distribution assumptions on the innovation process, and alternative specifications on the predictable price component.

15/00195 Multiagent study of smart grid customers with neighborhood electricity trading

Kahrobaee, S. *et al. Electric Power Systems Research*, 2014, 111, 123–132.

The smart grid of the future may equip customers with distributed generation and storage systems that can change their overall demand behaviour. Indeed, the smart grid's infrastructure provides new opportunities for the grid and its customers to exchange information regarding real-time electricity rates and demand profiles. Here the authors report on innovative agent-based modelling and simulation of a smart grid where active customers are modelled as self-interested, autonomous agents with their own specific load profiles and generation/storage capacities. They may choose to use locally generated power, charge/discharge their batteries, and manipulate their loads. A unique scenario for the customers analysed for this paper is one in which customers are allowed to trade electricity within their neighbourhood in order to minimize their electricity costs. Meanwhile, the grid prefers an overall uniform demand from all customers. To achieve this, an effective demand flattening management scheme was proposed for the customers. A model of the active customers within the smart grid environment is used to determine the impact of the neighbourhood power transactions, demand diversity, and load shifting on the customers and the utility. A number of case studies and sensitivity analyses have determined how and to what extent these parameters affect customer electricity costs and power system metrics.

15/00196 Opportunities for applying solvent storage to power plants with post-combustion carbon capture

Van Peteghem, T. and Delarue, E. *International Journal of Greenhouse Gas Control*, 2014, 21, 203–213.

One way of implementing carbon capture and storage (CCS) on fossil-fired power plants is by means of post-combustion capture. Regenerating the solvent and compressing the CO₂ in this process requires a significant amount of energy and therefore increases the cost of the produced electricity, as less electricity can be sold. By implementing solvent storage, this energy penalty can be delayed until moments with a low electricity price (i.e. more electricity could be sold when the electricity price is high and less when the electricity price is low). Investing in solvent storage, however, is only profitable if the profit increase is sufficiently high. This paper presents an analytical optimization framework for solvent storage implemented on a coal-fired power plant in an electricity market with a methodological, two-step electricity price profile (peak and off-peak). This analysis identifies distinct ranges of peak and off-peak price combinations in which solvent storage can lead to an increased profit. Depending on the problem parameters, these price ranges can vary, mostly depending on the emission certificate cost and the investment cost of the solvent storage infrastructure.

15/00197 Power portfolio optimization considering locational electricity prices and risk management

Lorca, Á. and Prina, J. *Electric Power Systems Research*, 2014, 109, 80–89.

This paper presents a medium-term power portfolio optimization model for a power producer in a competitive electricity market, considering locational electricity prices and risk management. The methodology developed includes modelling the multivariate stochastic evolution of locational electricity prices, the construction of a scenario tree that represents this evolution, and the formulation and solution of a stochastic optimization model. Using this methodology a power producer holding thermal generating units in more than one location may maximize expected profit while keeping a limited risk exposure. The model considers the possibility of trading electricity forward contracts in different locations and contracts for difference. In addition, its output includes amounts of electricity transactions in locational spot markets and power production in generating units. The computational experiments performed indicate that the correlation between locational electricity prices is very relevant for power producers holding generating units in those locations, since it significantly affects the relation between expected profit and risk.

15/00198 Qualitative analysis of strategies for the integration of renewable energies in the electricity grid

Trümper, S. C. *et al. Energy Procedia*, 2014, 46, 161–170.

Solar and wind electricity production with their volatile production patterns, have a high proportion in the renewable electricity production in the target frame of the German 'Energiewende'. The ratio of secure to non-secure generation capacity will increase to almost 1:1 in 2020 and thus further worsen the already existing problems in the integration of renewables into the grid. The consequence will be higher overall electricity supply costs. Solution options for this are grid expansion, more flexible generation in conventional power plants and demand-side control such as smart grids or smart markets. The latter offer rewarding capacities, especially in the heat demand. Although combined heat and power units can be used as a flexible, decentralized generation capacity, they have to be linked up and integrated accordingly. The need for flexible generation and balancing power requires additional energy storage. Next to pump storage facilities wind-hydrogen systems or stationary battery storage systems offer solutions to medium and large amounts electricity absorption and reinstate feeding into the grid. Due to the developments status of all these options, an appropriate regulatory framework for the market introduction is needed.

15/00199 Residual demand models for strategic bidding in European power exchanges: revisiting the methodology in the presence of a large penetration of renewables

Vázquez, S. *et al. Electric Power Systems Research*, 2014, 108, 178–184.

In the deregulated framework in place in most power systems, a significant part of the energy is traded through auctions on day-ahead markets where agents submit bids to either buy or sell energy. When defining a bidding strategy, generators usually resort to models that anticipate and simulate agent interactions. The residual demand curve (RDC), a well-known approach to representing competitor behaviour, enables generators to formulate effective oligopolistic strategies. One way to estimate and build an RDC is to use information available about other agents' bids on previous and comparable days as a reference. This basic approach to market modelling has proven useful in the past in European power exchanges. This paper analyses the suitability of single-firm optimization models based on RDC, focusing on methods that use historical data to build RDC scenarios for modelling day-ahead markets. In the context of European power exchanges these methods have traditionally provided a suitable trade-off between accuracy, the amount of competitor data needed to feed the model and computational requirements. The approach performs well when auctions are highly reminiscent of simple auctions in terms of behaviour and outcome. This study submits, however, that its applicability and accuracy decline under certain market conditions when complex conditions are widely used by generating companies. In particular, generating companies may obtain inaccurate estimates when substantial changes in variable renewable energy sources output are not offset by demand-side changes in the opposite direction. That premise is supported by the results observed in the Iberian electricity market in recent years.

15/00200 Survey of western U.S. electric utility resource plans

Wilkerson, J. *et al. Energy Policy*, 2014, 66, 90–103.

This study reviews the long-term electric utility plans representing ~90% of generation within the western USA and Canadian provinces. It addresses what utility planners assume about future growth of electricity demand and supply; what types of risk they consider in their long-term resource planning; and the consistency in which they report resource planning-related data. The region is anticipated to grow by 2% annually by 2020 – before demand-side management. About two-thirds of the utilities that provided an annual energy forecast also reported energy efficiency savings projections; in aggregate, they anticipate an average 6.4% reduction in energy and 8.6% reduction

in peak demand by 2020. New natural gas-fired and renewable generation will replace retiring coal plants. Although some utilities anticipate new coal-fired plants, most are planning for steady growth in renewable generation over the next two decades. Most planned solar capacity will come online before 2020, with most wind expansion after 2020. Fuel mix is expected to remain ~55% of total generation. Planners consider a wide range of risks but focus on future demand, fuel prices, and the possibility of greenhouse gas regulations. Data collection and reporting inconsistencies within and across electric utility resource plans lead to recommendations on policies to address this issue.

15/00201 Techno-economic assessments of oxy-fuel technology for South African coal-fired power stations

Oboirien, B. O. *et al. Energy*, 2014, 66, 550–555.

Oxy-fuel technology is one of the potential solutions to reduce CO₂ emissions from coal-fired power plants. Although vendors offer a 'retrofit package', to the best of the authors' knowledge there has not been a study undertaken that looks at the technical and economic viability of oxy-fuel technology for CO₂ capture for South African coal-fired power stations. This study presents a techno-economic analysis for six coal-fired power stations in South Africa. Each of these power stations has a total capacity of about 3600 MW. The analysis was done using the oxy-fuel model developed by Carnegie Mellon University, USA. The model was used to define the performance and costs of retrofitting the boilers. The results obtained showed that the CO₂ emission rate was reduced by a factor of 10 for all the plants when retrofitted to oxy-fuel combustion. Between 27% and 29% of the energy generated was used to capture CO₂. The energy loss was correlated to the coal properties. Sulfur content in the coal samples affects the energy used for flue gas cooling but did not affect the energy used for CO₂ purification and compression. The study also showed there is a need for the flue gas to be treated for NO_x and SO_x control. The total capital costs and cost of electricity for the six plants were different, resulting with the cost of electricity varying from \$101 to \$124/MWh.

15/00202 Vulnerability to terrorist attacks in European electricity decarbonisation scenarios: comparing renewable electricity imports to gas imports

Lilliestam, J. *Energy Policy*, 2014, 66, 234–248.

The decarbonized future European electricity system must remain secure: reliable electricity supply is a prerequisite for the functioning of modern society. Scenarios like Desertec, which partially rely on solar power imports from the Middle East and North Africa, may be attractive for decarbonization, but raise concerns about terrorists interrupting supply by attacking the long, unprotected transmission lines in the Sahara. This paper develops new methods and assesses the European vulnerability to terrorist attacks in the Desertec scenario. It compares this to the vulnerability of today's system and a decarbonization scenario in which Europe relies on gas imports for electricity generation. It shows that the vulnerability of both gas and electricity imports is low, but electricity imports are more vulnerable than gas imports, due to their technical characteristics. Gas outages (and, potentially, resulting blackouts) are the very unlikely consequence even of very high-number attacks against the gas import system, whereas short blackouts are the potential consequence of a few attacks against the import electricity lines. As the impacts of all except extreme attacks are limited, terrorists cannot attack energy infrastructure and cause spectacular, fear-creating outages. Both gas and electricity import infrastructure are thus unattractive and unlikely terrorist targets.

07 STEAM RAISING

Boiler operation/design

15/00203 Calculation code for helically coiled heat recovery boilers

Sogni, A. and Chiesa, P. *Energy Procedia*, 2014, 45, 492–501.

This paper describes a calculation code developed for helically coiled heat recovery boilers fed with exhaust gases from internal combustion engines, gas turbines or industrial processes. The code carries out the thermal rating calculation of the boiler by means of a one-dimensional model applicable to either water or thermal oil heating or steam generation in a once-through configuration. The paper is focused on the first case, in which cold fluid phase-change does not occur, and illustrates how the rating program can be helpful to improve the boiler

design with respect to the current standard, allowing a reduction of several percentage points in the calculated heat transfer area (and correspondingly weight and material cost) required for a given duty.

15/00204 Cold start-up condition model for heat recovery steam generators

Sindareh-Esfahani, P. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 502–512.

A dynamic modelling of a heat recovery steam generator (HRSG) during a cold start-up operation in combined cycle power plant (CCPP) is introduced. In order to characterize the essential dynamic behaviour of the HRSG during cold start-up, dynamic equations of all HRSG's components are developed based on energy and mass balances. To describe the operation of HRSG, a method based on non-linear estimated functions for thermodynamic properties is applied to estimate the model parameters. Model parameters are evaluated by a designed algorithm based on the genetic algorithm). A wide set of experimental data are used to validate the HRSG model during cold start-up operation. The simulation results show the reliability and validity of the developed model for cold start-up operation.

15/00205 Dynamic modeling of steam water system of prototype fast breeder reactor using RELAP code

Sharma, P. *et al. Annals of Nuclear Energy*, 2014, 68, 209–219.

The safety of a fast breeder reactor-based nuclear power plant with an intermediate coolant loop between the primary and tertiary circuit, depends on the correct functioning of actions initiated by the balance-of-plant (tertiary) systems. Comfortable time will be available for such actions to ensure reactor safety. Perturbations in the balance-of-plant (BoP) influence the transient sequence of safety-relevant parameters of the plant in a benign manner. However, for complete and realistic prediction of transient behaviour of the whole plant, dynamic models for BoP systems are required to be developed. This paper describes modelling of BoP system of PFBR using RELAP5/MOD 3.4 code. Some of the important transients in the BoP system, which are managed by reactor power setback procedure have been analysed using this code to verify the effectiveness of the procedure adopted.

15/00206 Effects of coolant flow rates on cooling performance of the intermediate pressure stages for an ultra-supercritical steam turbine

Huo, W. *et al. Applied Thermal Engineering*, 2014, 62, (2), 723–731.

The effects of the coolant flow rates on the thermal and flow fields of the first two intermediate pressure (IP) stages of an ultra-supercritical steam turbine was numerically investigated using the conjugate heat transfer (CHT) method, and the uncooled case was also simulated for comparison. The three-dimensional Reynolds-averaged Navier–Stokes solution was utilized to analyse the flow field and temperature distributions of the first two IP stages. The numerical results show that the steam cooling system has proved its ability to cool down the high temperature components, even in the case with the low coolant flow rate. The cooling performance can be improved with increased coolant flow rate, however, great flow losses would be induced and make the stage efficiency reduce by 1.23%. The different coolant flow rates also lead to great differences in the flow field in the front cavity of the first stage: ingress dominated flow condition with the low coolant flow rate and egress dominated flow condition with the high coolant flow rate. The negative influence of the ingested hot main steam on the cooling effect was also described.

15/00207 Efficiency and power upgrade by an additional high pressure economizer installation at an aged 620 MWe lignite-fired power plant

Stevanovic, V. D. *et al. Energy*, 2014, 66, 907–918.

An additional high-pressure economizer was installed at unit B1 of the 620 MWe lignite-fired Serbian power plant 'Nikola Tesla B' after 30 years of its operation. An innovative connection of the new additional economizer was applied. It is in parallel connection to the first section of the originally built economizer and it is directly fed with the feedwater from the outlet of the feedwater pump. The analysis of unit B1 operation with such an economizer arrangement is performed and it is supported by measured data. It is shown that more than 30 MWth of the flue gas waste heat is recovered. The unit's gross efficiency is increased by 0.53 percentage points, which leads to 9.4 MWe of the electric power production. The parallel connection of the additional economizer also leads to the partial feedwater bypass of the high pressure heaters, which enables an increase of the plant electric power by up to 24.5 MWe. The accompanying effects are the reduction of the pressure drop in the feedwater line and the economizers, which leads to the decrease of the energy consumption for the main feedwater pump operation. The applied solution is presented together with measured and calculated energy and economic benefits.

15/00208 Experiences in sulphur capture in a 30 MWth circulating fluidized bed boiler under oxy-combustion conditions

Gómez, M. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 617–622.

CO₂ and SO₂ from fossil fuel combustion are contributors to the greenhouse effect and acid rain, respectively. Oxy-combustion technology produces a highly concentrated CO₂ stream almost ready for capture. circulating fluidized bed (CFB) boiler technology allows *in situ* injection of calcium-based sorbents for efficient SO₂ capture. CIUDEN's 30 MWth CFB boiler, supplied by Foster Wheeler and located at the Technology Development Centre for CO₂ Capture and Transport (es.CO₂) in Spain, is the first of its kind for executing test runs at large pilot scale under both air-combustion and oxy-combustion conditions. In this work, SO₂ emissions under different scenarios have been evaluated. Variables such as limestone composition, Ca/S molar ratio and bed temperature among others have been considered along different test runs in both air-combustion and oxy-combustion conditions to analyse its influence on SO₂ abatement. Fly and bottom ash, together with flue gas analysis have been carried-out. Desulfurization performance tests results are presented.

15/00209 Experimental investigation into gas/particle flow in a down-fired 350 MWe supercritical utility boiler at different over-fire air ratios

Liu, C. *et al. Energy*, 2014, 64, 771–778.

Gas/particle two-phase flow experiments at different over-fire air ratios were conducted using a 1:20 small-scale model of a down-fired 350 MWe superficial utility boiler designed with multiple injections and multiple staging combustion technology. The mean velocity, fluctuating velocity and particle volume flux were measured using particle dynamics anemometer measurements. None of four conditions of pulverized coal short-circuit occurred. When the over-fire air percentage was 1.9% and after the arch air flow reached the tertiary air, the position of maximum gas flow velocity of the arch secondary air and the maximum particle volume flux in the fuel-rich flow was close to and eroded the furnace hopper side wall. When the over-fire air percentage was increased to 9.6%, the position of maximum gas flow velocity of the arch secondary air and the maximum particle volume flux in the fuel-rich flow started to deviate from the hopper side wall but did not erode the furnace side wall. However, when the over-fire air percentage was 9.6%, the gas velocity of the arch air flow entering the furnace hopper was still high and the arch air flow downstream depth was too deep. Therefore, use of an over-fire air percentage greater than 19.1% was recommended.

15/00210 Numerical and experimental study of a heat recovery steam generator during start-up procedure

Alobaid, F. *et al. Energy*, 2014, 64, 1057–1070.

The share of renewable energies in electricity and heat supply besides the conventional energy resources gains more importance. Accordingly, the efficiency and flexibility of modern thermal power plants should be further improved. To design such a system, it is necessary to generate detailed computer models that can accurately predict the power plant behaviour during fast transients, part loads and start-up procedures. In this work, a dynamic simulation model for a subcritical three-pressure-stage heat recovery steam generator (HRSG) is built, employing the advanced processing simulation software Aspen Plus Dynamics. The simulation results obtained from the HRSG model are validated towards the dynamic measurements during warm start-up procedure. The capability of processing simulation software used to estimate the dynamic behaviour of real HRSG is demonstrated. The HRSG model shows high accuracy at different part loads with a maximum relative error of about 5%. The good agreement suggests that the HRSG model is very reliable and is capable to predict the operational processes.

15/00211 Reducing energy consumption of a steam ejector through experimental optimization of the nozzle geometry

Sharifi, N. and Sharifi, M. *Energy*, 2014, 66, 860–867.

Steam ejectors use pressurized vapour as the motive flow for running in steam cycles. The major parameter that affects the thermal energy consumption is the pressure of motive flow used in this device. In this study, a malfunctioning experimental ejector is studied numerically to reveal the source of low evacuation rate from a suction chamber. This ejector was designed to operate under a motive pressure of 6 bar. However, the required vacuum in the suction vessel was not attained unless the pressure of motive steam was increased to 8 bar. The fastest and the most inexpensive way of improving the device performance was considered as replacing just the primary nozzle, with no further changes in ejector's body because, the ejector was connected to other unit facilities and hence the ejector replacement was very costly. The optimization procedure was performed through using numerical computational fluid dynamics (CFD) simulations. The shape of internal supersonic nozzle was changed in many CFD analyses and

the most optimized nozzle was selected for manufacturing. After installing the designed nozzle, an improved entrainment capability under the nominal pressure of 6 bar was observed and the desired vacuum level was attained.

15/00212 System-CFD coupled simulations of flow instability in steam generator U tubes

Watanabe, T. *et al. Annals of Nuclear Energy*, 2014, 70, 141–146.

The transient behaviour of flow instability in steam generator (SG) U-tubes is simulated numerically by performing system-computational fluid dynamics (CFD) coupled simulations. The system analysis code RELAP5 is used to simulate the overall system behaviour in the test facility, which consists of the heating loop and the model SG, and the commercial CFD code FLUENT is used to simulate detailed flow phenomena in the model SG. The flow conditions obtained by RELAP5 are used as the boundary conditions for FLUENT, and the calculated results by FLUENT are used for RELAP5. The flow instability with temperature fluctuation observed experimentally in the long U-tube is simulated well, and the downward flow is shown to occur simultaneously with the upward flow in one U-tube.

15/00213 Thermodynamic and experimental analysis of a biomass steam power plant: critical issues and their possible solutions with CCGT systems

Gimelli, A. and Luongo, A. *Energy Procedia*, 2014, 45, 227–236.

This paper shows the experimental and numerical analysis of a biomass steam power plant from maximum power of 2.3 MW with a maximum pressure of 48 bar and a turbine inlet temperature of about 430 °C at the design point. The analysis has been conducted using experimental data, collected directly on the power plant, at the design point, and they have been afterwards used to validate a thermodynamic model. The analysis of the biomass power plant pointed out some critical issues that can be summarized in three points: low plant efficiency due to the small size, biomass supply range and continuous variation of the operating point. In order to solve this problem, different plant configurations were numerically evaluated. The first solution to these problems consists of a 100 kW micro gas turbine (MGT) fuelled by natural gas, whose exhaust gas were sent to the steam generator of the biomass power plant in order to evaluate the benefits on the power fluctuations and on global electric efficiency. A thermodynamic model of the MGT has been developed and validated with experimental data from technical literature, creating a combined cycle gas turbine (CCGT) system. The analysis of the results of this system showed improvement in terms of efficiency and operational stability. The second option was to fuel the previously validated method of MGT with four different alternative fuels and to evaluate the integration with the biomass plant for all of them. Furthermore, to emphasize the benefits of this integration, the power of the micro turbine has been increased assuming the use of more MGT at the same time. These analyses show an increase of the system efficiency, it could be also used the biomass, not suitable for direct combustion (high humidity), to produce biogas that fuels the MGT, reducing the range of biomass supply.

was converted to NO₂ in the low-temperature (below 1000 K) zones. Emission indices of NO and CO both decreased with the increment of excess air ratio. They became rather small if the excess air ratio was maintained above 1.30 and 1.15, respectively. The effect of thermal load on the NO emission index was insignificant. The CO emission index increased considerably under the high load.

15/00215 Biomass co-firing under oxy-fuel conditions: a computational fluid dynamics modelling study and experimental validation

Álvarez, L. *et al. Fuel Processing Technology*, 2014, 120, 22–23.

This paper presents an experimental and numerical study on co-firing olive waste (0, 10%, 20% on mass basis) with two coals in an entrained flow reactor under three oxy-fuel conditions (21% O₂/79% CO₂, 30% O₂/70% CO₂ and 35% O₂/65% CO₂) and air-fuel condition. Co-firing biomass with coal was found to have favourable synergy effects in all the cases: it significantly improves the burnout and remarkably lowers NO_x emissions. The reduced peak temperatures during co-firing can also help to mitigate deposition formation in real furnaces. Co-firing CO₂-neutral biomass with coals under oxy-fuel conditions can achieve a below-zero CO₂ emission if the released CO₂ is captured and sequestered. The model-predicted burnout and gaseous emissions were compared against the experimental results. A very good agreement was observed, the differences in a range of approximately 5–10% of the experimental values, which indicates the model can be used to aid in design and optimization of large-scale biomass co-firing under oxy-fuel conditions.

15/00216 Biomass pyrolysis in a fixed-bed reactor: effects of pyrolysis parameters on product yields and characterization of products

Aysu, T. and Küçük, M. M. *Energy*, 2014, 64, 1002–1025.

Slow pyrolysis of eastern giant fennel (*Ferula orientalis* L.) stalks has been performed in a fixed-bed tubular reactor with (ZnO, Al₂O₃) and without catalyst at six different temperatures ranging from 350 to 600 °C with heating rates of 15, 30 and 50 °C/min. The amounts of bio-char, bio-oil and gas produced, as well as the compositions of the resulting bio-oils were determined by Fourier transform infrared spectroscopy and gas chromatography-mass spectrometry. The effects of pyrolysis parameters such as temperature, catalyst and ratio of catalyst, particle size (D_p) and sweeping gas flow rate on product yields were investigated. According to results, temperature and catalyst seem to be the main factors effecting the conversion of *F. orientalis* L. into solid, liquid and gaseous products. The highest liquid yield (45.22%) including water was obtained with 15% zinc oxide catalyst at 500 °C temperature at a heating rate of 50 °C/min when $0.224 > D_p > 0.150$ mm particle size raw material and 100 cm³/min of sweeping gas flow rate were used.

15/00217 Co-combustion studies for potential application of sawdust or its low temperature char as co-fuel with coal

Sarkar, P. *et al. Applied Thermal Engineering*, 2014, 63, (2), 616–623.

Co-combustion of biomass with pulverized coal is an important area under the clean energy development programme and the renewable energy development program in India, as well as in some other countries. However, biomass blending with coal requires investigation in terms of its possible application in existing pulverized fuel-fired boilers. A comparative assessment of the combustion performance for two types of binary blends, namely 'coal-sawdust (SD)' and 'coal-SD char' has been conducted in this study using a thermogravimetric analyser (TGA) and a drop tube furnace (DTF), based on this a judicious selection of blends may be made. Blends of either of the above fuels showed better performance in terms of major TGA-reactivity indices, ignition index and DTF-burn out efficiency as compared to coal-based performance (which was used as a bench mark). Activation energy for co-combustion in TGA showed synergistic effect. Between the two options of blend types, 'coal-SD char' appeared to be superior. Based on the fuel characteristics as well as operational issues, the use of SD-char may be considered a preferred option.

15/00218 Deposit analysis of water-wall tubes in a municipal solid waste grate incinerator

Lai, Z. Y. *et al. Applied Thermal Engineering*, 2014, 66, (1–2), 415–422.

To understand the deposition mechanism and determine the factors influencing corrosion, a municipal solid waste grate incinerator with the steam parameter of 6.5 MPa, 450 °C was investigated. Deposits from the first pass as well as fly ash were characterized by scanning electron microscopy with energy dispersive X-ray spectroscopy, X-ray fluorescence and X-ray diffraction. Deposits contained more or less molten or semi-molten materials, due to the chemical reaction heat during sulfation, low melting point compounds and molecular cramming. The content of K, Na, Cl or Fe in the deposits was bigger than fly ash, but fly ash contained more Ca, S, Si and Al, due to their different source and deposition mechanism. Chlorides and alkali metal compounds were identified. The molten deposits increased the

08 COMBUSTION

Burners, combustion systems

15/00214 An experimental and modeling study of NO_x and CO emission behaviors of dimethyl ether (DME) in a boiler furnace

Kang, T. *et al. Fuel Processing Technology*, 2014, 122, 129–140.

NO_x and CO emission behaviours of dimethyl ether/air premixed flame in a boiler furnace were studied by experimental and modelling approaches in this paper. Five excess air ratios (1.05, 1.15, 1.30, 1.45 and 1.60) and two thermal loads [high load (about 270 kW) and low load (about 130 kW)] were involved to investigate their effects on the emission behaviours. Besides, a chemical reactor network was constructed on the basis of computational fluid dynamics solutions to calculate NO and CO emissions. A detailed chemical mechanism of dimethyl ether combined with the San Diego NO_x chemistry which includes thermal, prompt, N₂O and NO₂ pathways was used. The research indicated that NO in the flame base was formed via a combination of thermal, prompt and N₂O pathways. The thermal pathway dominated in the high-temperature (above 1800 K) flame zone. NO in intermediate-temperature (1000–1600 K) regions was generated via the NO₂ pathway. Besides, a considerable amount of NO

corrosion because liquid phase had faster chemical reactions and also provided an electrolyte for ionic transport or electrochemical attack. The chlorides and alkali metal compounds accelerated corrosion not only by lowering the melting temperature of the deposits, but also by attacking the metal surface with active oxidation mechanism. Moreover, entirety of deposits had a high strength, therefore, deposits were subject to stress impact and resulted in the metal defect on the heating tubes.

15/00219 Effect of overfire air angle on flow characteristics within a small-scale model for a deep-air-staging down-fired furnace

Kuang, M. *et al. Energy Conversion and Management*, 2014, 79, 367–376.

A deep-air-staging combustion technology consisting of special combustion organization and overfire air (OFA) application, has been developed previously for the particularly high NO_x emissions, severely asymmetric combustion, and serious slagging that were found in a 350 MW_e down-fired furnace. To evaluate the flow characteristics with respect to the OFA angle and thus establish an optimal OFA angle for the furnace, cold airflow experiments were conducted by recording flow field data within a 1:15-scaled model of the furnace at different OFA angle settings (i.e. 30°, 35°, 40°, 45° and 50°, respectively). Various data such as the flow field pattern, velocity distribution in the furnace throat region where OFA flows, and the decay in the OFA jet, were compared among different angle settings. No negative effect on the flow field could be found with increasing the OFA angle except for 50°. As the angle increased, the vertical reach of the OFA flow increased continually, whereas the transverse spread of OFA increased initially but then decreased in the furnace throat region. To establish a symmetric flow field along with an appropriate OFA penetration depth, an optimal setting of 40° was found for the OFA angle. The numerical results show that applying the deep-air-staging combustion technology with the optimized OFA angle, well-formed symmetric combustion developed and NO_x emissions could be reduced by 50%, without increasing levels of carbon in fly ash.

15/00220 Emission performance of type-1 pulverized coal flames operating under oxy-fired conditions

da Silva, R. C. and Krautz, H. J. *Applied Thermal Engineering*, 2014, 64, (1–2), 430–440.

This study addresses the emission performance (CO , NO_x , SO_2) on pulverized coal flames generated by a staged feed-gas burner operating with pre-dried lignite under oxy-fired conditions. While previous studies provided information on the impacts of recycle ratios and O_2 fraction, this work focuses on the impacts of swirl strength and feed gas distribution on the combustion process. The overall O_2 fraction upstream of the burner operating under oxy-fired condition was defined with basis on a similar adiabatic flame temperature as air-firing. Images obtained with visualization techniques show evidence of a stratified flame structure resembling a diffusion type-1 flame. Measurements of CO concentration and particle burnout at the furnace exit indicated that carbon in ash is not an obstacle for the use of staged feed-gas burner in oxy-firing. Experimental results do show a great potential for NO abatement through an appropriate burner setting. In particular, a combination of high swirl strength and high secondary/tertiary flow ratio results in significant NO reduction. Evaluation of SO_2 levels show that oxy-fuel combustion does not affect the release of sulfur from the pre-dried lignite under the conditions evaluated in this work, indicating that SO_2 emissions are exclusively dependent on the sulfur content of the coal.

15/00221 Heating characteristics of billet in a walking hearth type reheating furnace

Emadi, A. *et al. Applied Thermal Engineering*, 2014, 63, (1), 396–405.

The heating characteristics of billet in a walking hearth type reheating furnace were studied by developing a mathematical heat transfer model. Radiation calculations were conducted by means of zone method and considering all radiation exchange paths. The weighted-sum-of-grey-gas-model was used for better accuracy of gas radiation prediction. Convective heat flux was calculated by considering suitable value of convective heat transfer coefficient at any location of the furnace. The model was substantiated through its comparison to experimental data. A comparison was drawn to evaluate the effect of constant and variable convective coefficient on convective flux distribution and billet thermal behaviour. The effect of furnace wall's emissivity of each zone and whole of the furnace on the billet thermal behaviour was investigated. The obtained results revealed that by increasing furnace wall's emissivity for a determined residence time, billet's temperature in primary zones rises but it has no significant effect on its final temperature. However, by increasing wall's emissivity from 0.7 to 0.95, the residence time can be declined by about 5%. Moreover, emissivity increase in non-firing and preheating zones as compared to heating and soaking zones has greater impact on the billet thermal behaviour.

15/00222 Pyrolysis of coal in TGA: extent of volatile condensation in crucible

Shi, L. *et al. Fuel Processing Technology*, 2014, 121, 91–95.

Thermal gravimetric analysis (TGA) with crucibles of different shapes and sizes are used to evaluate reactions of volatiles generated from pyrolysis of two coals based on the understandings obtained from decomposition of CaCO_3 and polyvinylpyrrolidone. The TGA experiments were carried out in a flow of argon at a heating rate of 10°Cmin^{-1} . The decomposition of CaCO_3 shows an increase in derivative thermal gravimetric (DTG) peak temperature with an increase in the sample height or in the free space volume in the crucibles, which are attributed to the reverse reaction between the volatile product CO_2 and the solid product CaO . The depolymerization of Polyvinylpyrrolidone supported on a coal-derived coke shows a decrease in DTG peak depth with an increase in the sample height or in the free space volume of the crucibles, indicating that the volatile intermediates generated from the depolymerization are reactive to form solid. The DTG curves of the two coals are very similar. They show a main pyrolysis peak which varies little with changes in the sample height and in the free space volume in the crucibles, suggesting that the extent of volatiles' reaction to form solid in the crucibles is very limited.

15/00223 Simulations of pulverized coal oxy-combustion in swirl burner using RANS and LES methods

Warzecha, P. and Boguslawski, A. *Fuel Processing Technology*, 2014, 119, 130–135.

Oxy-combustion is a technology that is used to reduce the emission of greenhouse gases to the atmosphere. Adaptation of the existing systems to burn coal in oxy-combustion technology requires a number of studies that can be greatly supported by numerical investigations – computational fluid dynamics (CFD). The paper presents results of pulverized coal combustion process in swirl burner using Reynolds-averaged Navier–Stokes equations (RANS) and large eddy simulation (LES) methods for turbulent flow. Numerical simulations have been performed for oxy-combustion technology for various ratio of oxygen in the oxidizer and compared to conventional combustion in air. Comparison of the air and oxy-coal combustion process for pulverized coal shows significant differences in temperature, especially the temperature close to the burner exit. In order to represent the conventional coal combustion process, oxidizer should contain about 30% of oxygen in the O_2/CO_2 mixture.

15/00224 Surface ignition behaviors of methane–air mixture in a gas oven burner

Ryu, J. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 262–272.

In a gas oven burner, commonly used as a residential appliance, a surface igniter is a critical component for creating a pilot flame near the surface that can propagate safely back to the nozzle of the burner. The igniter should meet critical operating requirements: a lower surface temperature needed to ignite a methane–air mixture and a stable/safe ignition sustained. Otherwise, such failure would result in an instantaneous peak in carbon monoxide emission and a safety hazard inside a closed oven. Several theoretical correlations have been used to predict ignition temperature as well as the critical ignition/extinction limit for a stagnation flow ignition. However, there have only been a few studies on ignition modes or relevant stability analysis, and therefore a more detailed examination of the transient ignition process is required. In this study, a high-speed flame visualization technique with temperature measurement was employed to reveal a surface ignition phenomenon and subsequent flame propagation of a cold combustible methane–air mixture in a gas oven burner. The operating parameters were the temperature–time history of the igniter surface, mixture velocity, and the distance of the igniter from the nozzle. The surface ignition temperatures were analysed for such parameters under a safe ignition mode, while several abnormal modes leading to ignition failure were also recognized.

15/00225 Torrefaction of agriculture straws and its application on biomass pyrolysis poly-generation

Chen, Y. *et al. Bioresource Technology*, 2014, 156, 70–77.

This study investigated the properties of corn stalk and cotton stalk after torrefaction, and the effects of torrefaction on product properties obtained under the optimal condition of biomass pyrolysis poly-generation. The colour of the torrefied biomass chars darkened, and the grindability was upgraded, with finer particles formed and grinding energy consumption reduced. The moisture and oxygen content significantly decreased whereas the carbon content increased considerably. It was found that torrefaction had different effects on the char, liquid oil and biogas from biomass pyrolysis poly-generation. Compared to raw straws, the output of chars from pyrolysis of torrefied straws increased and the quality of chars as a solid fuel had no significant change, while the output of liquid oil and biogas decreased. The liquid

oil contained more concentrated phenols with less water content below 40 wt%, and the biogas contained more concentrated H_2 and CH_4 with higher LHV up to 15 MJ/nm³.

Fire safety

15/00226 API Standard 521 new alternative method to evaluate fire relief for pressure relief device sizing and depressuring system design

Zamejc, E. *Journal of Loss Prevention in the Process Industries*, 2014, 27, 21–31.

Since the 1950s, API Standards have provided guidance on determining relief loads for equipment exposed to pool fires. The API method is empirical based on tests performed in the 1940s. There is increasingly widespread interest in analytical methods based on heat transfer principles to model fire heat input. The API committee agreed to include an analytical method in the sixth edition of API Standard 521 to establish relief loads for pressure relief devices and to design depressuring systems for the fire scenario. The analytical method provides more flexibility than the empirical method but has limitations (e.g. too many permutations are possible leading to potential under-sizing of the pressure relief device). This paper discusses the basis for the empirical method in API Standard 521 and provides comparisons of the empirical and analytical method with two more recent large-scale pool fire tests. This pool fire test data indicates that the empirical method will provide a conservative estimate of pool fire heat input for most applications and is still the method of choice when designing pressure relief systems. However, these recent tests indicate the empirical method needs to be modified when a vessel or equipment is partially confined by adjacent embankments or walls equal or greater than the vessel height. In such cases, the wetted area exponent should be 1.0 instead of 0.82. The analytical method is useful in determining time-versus-temperature profiles for heating unwetted vessels of varying wall thicknesses and materials of construction. These profiles, which depend upon the type of fire (e.g. unconfined pool fire, jet fire, etc.), can be combined with tensile strength and stress-rupture data to specify a depressuring system's pressure-versus-time profile. This will minimize failure and/or mitigate the effects of failure due to overheating from fire exposure.

15/00227 Effects of hydrogen addition on the confined and vented explosion behavior of methane in air

Ma, Q. *et al. Journal of Loss Prevention in the Process Industries*, 2014, 27, 65–73.

Multi-component gas mixture explosion accidents occur and recur frequently, while the safety issues of multi-component gas mixture explosion for hydrogen-methane mixtures have rarely been addressed. Numerical simulation study on the confined and vented explosion characteristics of methane-hydrogen mixture in stoichiometric air was conducted both in the 5 L vessel and the 64 m³ chamber, involving different mixture compositions and initial pressures. Based on the results and analysis, it is shown that the addition of hydrogen has a negative effect on the explosion pressure of methane-hydrogen mixture at adiabatic condition. While in the vented explosion, the addition of the hydrogen has a significant positive effect on the explosion hazard degree. Additionally, the addition of hydrogen can induce a faster reactivity and enhance the sensitivity of the mixture by reducing the explosion time and increasing the rate of pressure rise both in confined and vented explosion. Both the maximum pressure and the maximum rate of pressure rise increase with initial pressure as a linear function, and also rise with the increase of hydrogen content in fuel. The increase in the maximum rate of pressure rise is slight when hydrogen ratio is lower than 0.5, however, it become significant when hydrogen ratio is higher than 0.5. The maximum rate of pressure rise for stoichiometric hydrogen-air is about 10 times the one of stoichiometric methane-air. Furthermore, the vent plays an important role to relief pressure, causing the decrease in explosion pressure and rate of pressure rise, while it can greatly enhance the flame speed, which will extend the hazard range and induce secondary fire damages. Additionally it appears that the addition of hydrogen has a significant increasing effect on the flame speed. The propagation of flame speed in confined explosion can be divided into two stages, increase stage and decrease stage, higher hydrogen content, higher slope. But in the vented explosion, the flame speed keeps increasing with the distance from the ignition point.

15/00228 The effect of azeotropism on combustion characteristics of blended fuel pool fire

Ding, Y. *et al. Journal of Hazardous Materials*, 2014, 271, 82–88.

The effect of azeotropism on combustion characteristics of blended fuel pool fire was experimentally studied in an open fire test space of State Key Laboratory of Fire Science. A 30 cm × 30 cm square pool filled with n-heptane and ethanol blended fuel was employed. Flame images, burning rate and temperature distribution were collected and recorded in the whole combustion process. Results show that azeotropism obviously dominates the combustion behaviour of n-heptane/ethanol blended fuel pool fire. The combustion process after ignition exhibits four typical stages: initial development, azeotropic burning, single-component burning and decay stage. Azeotropism appears when temperature of fuel surface reaches azeotropic point and blended fuel burns at azeotropic ratio. Compared with individual pure fuel, the effect of azeotropism on main fire parameters, such as flame height, burning rate, flame puffing frequency and centreline temperature were analysed. Burning rate and centreline temperature of blended fuel are higher than that of individual pure fuel respectively at azeotropic burning stage, and flame puffing frequency follows the empirical formula between Strouhal and Froude number for pure fuel.

15/00229 The EFFIS forest fire atmospheric emission model: application to a major fire event in Portugal

Monteiro, A. *et al. Atmospheric Environment*, 2014, 84, 355–362.

Forest fires are a major contributor of gaseous and particulate compounds to the atmosphere, impairing air quality and affecting human health. A new forest fire emissions module was developed and integrated into the European Forest Fire Information System (EFFIS), which systematically compiles, since 2000, series of burnt area statistics mapped from satellite imagery. This new forest fire emission model was built on classical methodologies of fuel-map based emission estimation that were improved, especially on burning efficiency, fuel consumption estimation and emission factors. It makes the best use of EFFIS near-real time and detailed information on forest fires, mainly concerning products with a high temporal resolution, which is needed to simulate smoke dispersion and chemical transformation in the atmosphere. A case study of a forest fire event in the north of Portugal on 14 October 2011, with a total of 4400 ha of burnt area, was selected to test this forest fire emission model. The fine scale information used in this study included: (1) 3-h resolution meteorological fields; (2) daily evolution of the cumulative fire perimeter from the EFFIS rapid damage assessment system; and (3) a fine spatial resolution fuel map, forest type map and topography. The 3-h evolution of pollutant emissions was calculated for gas and particulate species based on the evolution of the burnt area increase and fuel consumption. The estimated forest fire emissions represent more than 90% of the total annual (anthropogenic and natural) emissions over the study region. The impact of these forest fire emissions was analysed in terms of air quality, using observational data from the nearest air quality monitoring station. High peaks of NO₂ and SO₂ were registered simultaneously during the period 06–09 a.m. and a later peak of particulate matter from 7 a.m. to 3 p.m.

15/00230 Thermo-hydric transfer within timber connections under fire exposure: experimental and numerical investigations

Samaké, A. *et al. Applied Thermal Engineering*, 2014, 63, (1), 254–265.

Connections within timber structures are highly vulnerable areas when exposed to fire, especially when made of fasteners with different thermal and mechanical properties. This mechanical cohabitation can generate, because of material permeability differences, additional physicochemical phenomena. These phenomena are affected by the coupling of heat and moisture transfers, which can alter the mechanical behaviour of timber structures. In order to improve the knowledge of the thermo-hydric timber connection, a series of experimental tests has been carried out and numerical models have been developed by taking the experimental observations into account. The experimental campaign concerns timber-to-timber and timber-steel-timber connections exposed to an ISO 834 fire. The connections studied are real joints made of timber members, with and without a median metal plate, and maintained using bolts or dowels. The present study was conducted to examine heat transfer while taking the hydric effects at the interface between timber and steel fasteners into account. To analyse the experimental results and adjust the thermophysical parameters for numerical modelling, numerical thermal fields, finite differences and finite elements, models are developed. Numerical and experimental results are in good agreement. Nevertheless, some observations are made and discussed by comparing numerical results with experimental ones.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

15/00231 A hybrid DEM/CFD approach for solid-liquid flows

Qiu, L.-c. and Wu, C.-y. *Journal of Hydrodynamics, Ser. B*, 2014, 26, (1), 19–25.

A hybrid scheme coupling the discrete element method (DEM) with the computational fluid dynamics (CFD) is developed to model solid-liquid flows. Instead of solving the pressure Poisson equation, the authors used the compressible volume-averaged continuity and momentum equations with an isothermal stiff equation of state for the liquid phase in the CFD scheme. The motion of the solid phase was obtained by using the DEM, in which the particle-particle and particle-wall interactions are modelled by using the theoretical contact mechanics. The two phases were coupled through the Newton's third law of motion. To verify the proposed method, the sedimentation of a single spherical particle was simulated in water, and the results compared with experimental results reported in the literature. In addition, the drafting, kissing, and tumbling phenomenon between two particles in a liquid was modelled and reasonable results obtained. Finally, the numerical simulation of the density-driven segregation of a binary particulate suspension involving 10,000 particles in a closed container was conducted to show that the method is potentially powerful in simulating real particulate flows with large number of moving particles.

15/00232 Analysis of the parameters affecting energy consumption of a rotary kiln in cement industry

Atmaca, A. and Yumrutaş, R. *Applied Thermal Engineering*, 2014, 66, (1–2), 435–444.

In this study, the effects of refractory bricks and formation of anast layer on the specific energy consumption of a rotary kiln are investigated. Thermodynamic analysis of the kiln is performed to achieve effective and efficient energy management scheme. Actual data, which are taken from a cement plant located in Gaziantep, Turkey, are used in numerical calculations to obtain energy balance for the system. It is calculated that 12.5 MW of energy is lost from the surface of the kiln which accounts for the 11.3% of the total energy input to the unit. The specific energy consumption for clinker production is determined to be 3735.45 kJ/kg clinker. The formation of anast layer and the use of high quality magnesite spinel and high alumina refractory bricks provide 7.27% reduction in energy consumption corresponding to a saving of 271.78 MJ per ton of clinker production. It is recognized that the anast layer has an important role for durability of the refractory bricks and heat transfer out of the kiln. The applications prevent the emission of 1614.48 tons of CO₂ per year to the atmosphere.

15/00233 Battery thermal management by boiling heat-transfer

van Gils, R. W. *et al. Energy Conversion and Management*, 2014, 79, 9–17.

In this study, the ability of a boiling process to thermally condition (homogenization and cooling) batteries is investigated. A series of experiments are performed and discussed. Subjects that are treated are the dielectric property of the proposed cooling fluid, its cooling capability compared to that of air, the ability of the boiling fluid to thermally homogenize a battery and the influence of pressure variation on the boiling process. It turns out that the proposed cooling fluid conducts no electricity, has good cooling characteristics compared to those of air and, when boiling, is able to thermally homogenize the battery. Furthermore, pressure variation seems to offer a good method to regulate the boiling process.

15/00234 Carbon intensity in production and the effects of climate policy – evidence from Swedish industry

Brännlund, R. *et al. Energy Policy*, 2014, 67, 844–857.

This study analysed carbon intensity performance at firm level and the effectiveness of the Swedish CO₂ tax. Carbon intensity performance is derived from a production technology and measured as changes in the CO₂ emission-output production ratio. As one of the first countries to introduce a CO₂ tax in 1991, Sweden serves as an appropriate 'test bench' for analysing the effectiveness of climate policy in general. Firm level data from Swedish manufacturing spanning over the period 1990–2004 is used for the analysis. Results show that environmental

performance has improved in all the sectors and there is an evidence of decoupling of output production growth and CO₂ emissions. Firms' carbon intensity performance responds both to changes in the CO₂ tax and fossil fuel price, but is more sensitive to the tax.

15/00235 China's total factor energy efficiency of provincial industrial sectors

Xiaoli, Z. *et al. Energy*, 2014, 65, 52–61.

The index of total-factor energy efficiency (TFEE) is used to assess the level of energy consumption to produce economic output (gross domestic product) based on multi-factor input, which is superior to conventional energy efficiency evaluation regarded as a partial-factor energy efficiency index. The objective of this study is to provide the changes of TFEE at sector and provincial level and to illustrate the drivers behind such various changes in China. The results show that the TFEE of most industrial sectors in the eastern provinces is higher than that in other provinces. The most important finding is that the gap of TFEE across sectors was narrowed in the eastern provinces and expanded comparatively in the central and western provinces. Such result implies that the gap reduction of TFEE across sectors would be one of the important drivers behind the increase of overall TFEE. Meanwhile, the Tobit regression results indicate that technology progress, energy price and economic development have positive influence on TFEE. And the impact of technology progress is found to be of the most significance.

15/00236 Clean energy industries and rare earth materials: economic and financial issues

Baldi, L. *et al. Energy Policy*, 2014, 66, 53–61.

In the past few years, rare earth material (REM) prices have experienced a strong increase due to geopolitical and sustainability issues. Financial markets could already have factored in concerns about shortages of REM supplies into clean energy companies' valuations. The authors use a multifactor market model for the period January 2006 to September 2012 to analyse the impact of REM price trends – specifically dysprosium and neodymium – on six clean energy indices (NYSE-BNEF) tracking the world's most important companies in the clean energy sector. The results show that during period of price increase, there is a negative relationship between REM price changes and the stock market performance of some clean energy indices. The European clean energy index is also negatively affected, and this effect could be relevant to policy makers, considering that the European Union is implementing some relevant policy actions to support the development of the clean energy industry.

15/00237 Design of a thermoacoustic heat engine for low temperature waste heat recovery in food manufacturing: a thermoacoustic device for heat recovery

Mumith, J.-A. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 588–596.

There is currently an urgent demand to reuse waste heat from industrial processes with approaches that require minimal investment and low cost of ownership. Thermoacoustic heat engines (TAHEs) are a kind of prime mover that convert thermal energy to acoustic energy, consisting of two heat exchangers and a stack of parallel plates, all enclosed in a cylindrical casing. This simple design and the absence of any moving mechanical parts make such devices suitable for a variety of heat recovery applications in industry. In this present work the application of a standing-wave TAHE to utilize waste heat from baking ovens in biscuit manufacturing is investigated. An iterative design methodology is employed to determine the design parameter values of the device that not only maximize acoustic power output and ultimately overall efficiency, but also utilize as much of the high volume waste heat as possible. At the core of the methodology employed is DeltaEC, a simulation software which calculates performance of thermoacoustic equipment. The investigation has shown that even at such a comparatively low temperature of 150 °C it is possible to recover waste heat to deliver an output of 1029.10 W of acoustic power with a thermal engine efficiency of 5.42%.

15/00238 Design of dual column water purification system for industrial gamma irradiator based of PUROLITE® resins

Aghoyeh, R. G. and Khalafi, H. *Annals of Nuclear Energy*, 2014, 69, 90–96.

When gamma irradiators are not in use, they have to be stored in nuclear grade water pool. This water serves as shielding and the medium for the removal of generated heat. To prevent corrosion damage to the gamma source and other equipment a purification system controls the water quality. Also, this system serves as the make-up water system for supplies and maintains the de-ionized water level in the gamma source storage pool. In this paper, the design of the dual system for purification and make-up water for optimal water supply and its chemical parameters in the gamma source storage pool is presented. For this purpose, the characteristics of activated carbon purifier, anionic and cationic demineralizers have been determined.

'Aerb Safety Standard', 'Purolite Ion Exchange Design Code' and 'Canadian Water Refining Company Manual' have been used to design IR-136 gamma irradiator storage pool purification and make-up water system. The main objective of the design is to maintain water purity throughout the storage time.

15/00239 Economic evaluation of the conversion of industrial paper sludge to ethanol

Chen, H. *et al. Energy Economics*, 2014, 44, 281–290.

The conversion of industrial paper sludge to ethanol was simulated using engineering process simulation software loaded with laboratory generated conversion data and financially analysed. In one scenario, sludge is fractionated to remove ash, generating a higher concentration carbohydrate stream for separate hydrolysis and fermentation. In a second scenario, non-fractionated sludge is processed with only pH adjustment. Four primary sludges from mills producing either virgin or recycled paper were analysed and the experimental conversion results used to inform the simulations. Financial analysis was conducted assuming ethanol wholesale price of US\$0.608/litre. The most profitable case was fractionated virgin sludge (from a virgin paper mill) to ethanol (F-VK1) with a net present value (NPV) of \$11.4 million, internal rate of return of 28%, payback period of 4.4 years and minimum ethanol revenue of \$0.32/litre. Risk analysis showed that the F-VK1 case obtained a near 100% probability of business success with both central and bearish (pessimistic) assumptions.

15/00240 Effect of flue gas recirculation during oxy-fuel combustion in a rotary cement kiln

Granados, D. A. *et al. Energy*, 2014, 64, 615–625.

The effect of flue gas recirculation (FGR) during oxy-fuel combustion in a rotary cement kiln was analysed by using a computational fluid dynamics (CFD) model applied to coal combustion process. The CFD model is based on three-dimensional balance equations for mass, species, energy and momentum. Turbulence and radiation model coupled to a chemical kinetic mechanism for pyrolysis processes, gas–solid and gas–gas reactions was included to predict species and flame temperature distribution, as well as convective and radiation energy fluxes. The model was used to study coal combustion with air and with oxygen for FGR between 30% and 85% as controller parameter for temperature in the process. Flame length effect and heat transfer by convection and radiation to the clinkering process for several recirculation ratios was studied. Theoretical studies predicted a located increase of energy flux and a reduction in flame length with respect to the traditional system which is based on air combustion. The impact of FGR on the oxy-fuel combustion process and different energy scenarios in cement kilns to increase energy efficiency and clinker production were studied and evaluated. Simulation results were in close agreement with experimental data, where the maximum deviation was 1%.

15/00241 Energy audit of an industrial site: a case study

Dongellini, M. *et al. Energy Procedia*, 2014, 45, 424–433.

In order to reduce energy consumptions for sustainable and energy-efficient manufacturing, continuous energy audit and process tracking of industrial machines are essential. Compared to other non-residential buildings that have been widely researched, industrial buildings are generally characterized by larger thermal loads, ventilation losses and pollution control requirements. This paper presents the results of a preliminary energy audit carried out on eight large industrial buildings of a famous car manufacturing holding in Italy. Energy demand for heating varied from 6 to just over 74 kWh/m³ year among the buildings of the site. The energy audit enabled to build a specific factory energy model which has been used in order to analyse the impact of various energy saving actions on the primary energy consumptions of the site. It has been demonstrated that in this specific case the improvement of the building envelopes and the optimization of the performances of the existing heating, ventilation and air-conditioning systems can determine a reduction of gas consumption up to 15% per year with a predicted annual economic saving of the order of €100,000; the total simple pay-back time of the proposed thermal retrofitting is evaluated to be less than 6 years.

15/00242 Energy propagation in plasma arc welding with keyhole tracking

Li, Y. *et al. Energy*, 2014, 64, 1044–1056.

A three-dimensional mathematical model was developed to research the dynamic interaction between energy propagation and keyhole evolution in plasma arc welding (PAW). Particularly, a keyhole-tracking heat source model was proposed to reflect the energy propagation in the wake of keyhole evolution, which was tracked by the volume of fluid technique. The model consists of a Gaussian heat flux on top surface and a lower developing conical heat source related to the dynamic keyhole growth. In addition, a dynamic energy distribution coefficient was established, bound up with the keyholing process for the first time. The design of this heat transfer model

introduces the analogy to actual energy propagation in experiment. Evolution of the dynamic energy density distribution concerning keyhole effect was analysed in details, and the corresponding temperature field was calculated and displayed to reveal the mechanism of thermal process in the workpiece. Furthermore, the keyholing process and molten metal flow in the weld pool were investigated to exhibit how the keyhole promotes the deep penetration welding. Finally, the experiments were carried out on the stainless steel plate, and the measured weld bead geometry, keyhole size and time for workpiece completely penetrated through were all close to simulation results.

15/00243 Energy transfer diagram for improving integration of industrial systems

Bonhivers, J.-C. *et al. Applied Thermal Engineering*, 2014, 63, (1), 468–479.

In industrial processes, heat is transferred from the heating utilities to the environment or converted to another form of energy. Process operations and heat exchanges decrease the energy quality, i.e. the heat is cascaded to lower temperatures. This paper focuses on the energy retrofit analysis by screening the transfer of energy across process operations and heat exchangers. A new conceptual diagram is proposed to capture the flow rate of heat transferred from the heating utilities to the environment through each heat exchanger and process operation as a function of temperature. The diagram considers heat savings by retrofit of the process units and the heat exchanger network (HEN), which was not fully addressed by previous methods. As an example of application, the diagram is used to identify heat saving modifications in a furfural process, alone or hosted in a kraft pulp mill. The heat consumption in the furfural process alone can be reduced by 40% by two modifications in the HEN; the net heat consumption in the furfural process hosted in a kraft pulp mill can be reduced by 60–84% with a few simple modifications in the HEN and process operations.

15/00244 Environmental impact of a granite processing factory as source of naturally occurring radionuclides

Guillén, J. *et al. Applied Geochemistry*, 2014, 47, 122–129.

The extraction and processing of ornamental stone, and granite in particular, generates a huge amount of wastes, which are usually disposed into slag heaps and subjected to weathering. Granite can present high content of naturally occurring radionuclides (⁴⁰K, ^{226,228}Ra, ^{234,238}U, ²¹⁰Po and ^{228,230,232}Th). A small-scale granite processing company was selected, and the generated wastes, mainly scraps and slurries, presented almost the same activity levels, since only physical processes (cutting) were used. Uranium and ⁴⁰K content in the water used in the factory as coolant were enhanced regarding its original value, as a consequence of its contact with the slurries. Other physicochemical parameters of the water (pH, conductivity, Cl, K, Na, Mg) also increased. The environmental behaviour of naturally occurring radionuclides contained in solid wastes, scraps and slurries, were assessed by means of a sequential extraction procedure. Uranium in scraps and slurries was mainly associated with diluted-acid (HCl 1 M), concentrated-acid (HCl 6 M), and residual fractions; while ⁴⁰K was almost exclusively associated with the residual fraction. The readily bioavailable fraction (water soluble + exchangeable) in scrap and slurry were lower than 20%, and decreased in the following order: ^{226,228}Ra > ^{234,238}U > ⁴⁰K > ²¹⁰Po ≈ ^{228,230,232}Th.

15/00245 Estimation of energy saving potential in China's paper industry

Lin, B. and Moubarak, M. *Energy*, 2014, 65, 182–189.

The objective of this paper is to estimate the energy-saving potential in China's paper industry by determining energy intensity under different scenarios. A cointegration model and a stability test are applied to formulate the equilibrium equation. Results show that energy price, industry structure, profit margin and technology have significant impact as they are negatively correlated to changes in energy intensity. Three scenarios [business as usual (BAU), intermediate and active] are designed to estimate the future trend of energy intensity in paper industry. In 2010, the energy intensity (energy consumption per unit of value added) was 4 tce/10,000 RMB, and by the scenarios it is expected to considerably decline. According to the BAU scenario, the energy intensity will decrease to 2.56, 1.43 and 0.70 tce/10,000 RMB by 2015, 2020 and 2025, respectively. With respect to the intermediate scenario it is expected to drop further to 0.44 tce/10,000 RMB. Yet by the active scenario, the energy intensity is expected to considerably decline to 0.36 tce/10,000 RMB by 2025. Using the BAU forecast as a baseline, the quantity of energy savings is estimated to be 185.6 billion tce by 2025. Considering this important potential, the author also provided some policy suggestions.

15/00246 Flotation process design based on energy input and distribution

Gui, X. *et al. Fuel Processing Technology*, 2014, 120, 61–70.

Energy-saving ability and high flotation efficiency are two important factors in the flotation process. In this investigation, a new concept for the flotation process design based on energy input and distribution was proposed, low energy was inputted early to recover easy-to-float materials, whereas high energy was inputted late to recover difficult-to-float materials. The flotation tests were conducted in an XFD 0.75 L laboratory-scale flotation machine. A comparison of flotation performance using constant power input and gradually increased power input was investigated. The flotation results indicated that low ash content, high flotation efficiency index, and energy-saving ability could be obtained by increasing power input step by step in the flotation process. The flotation process design based on different shaft speeds (1500, 1500, 1800, 1800 and 2400 rev/min in different flotation periods) and an energy consumption of 1720.8 J is suitable for flotation performance of the coal samples in this study.

15/00247 Fuel sparing: control of industrial furnaces using process gas as supplemental fuel

Boisvert, P. G. and Runstedtler, A. *Applied Thermal Engineering*, 2014, 65, (1–2), 293–298.

Combustible gases from industrial processes can be used to spare purchased fuels such as natural gas and avoid wasteful flaring of the process gases. One of the challenges of incorporating these gases into other furnaces is their intermittent availability. In order to incorporate the gases into a continuously operating furnace, the furnace control system must be carefully designed so that the payload is not affected by the changing fuel. This paper presents a transient computational fluid dynamics (CFD) model of an industrial furnace that supplements natural gas with carbon monoxide during furnace operation. A realistic control system of the furnace is simulated as part of the CFD calculation. The time dependent changes in fuels and air injection on the furnace operation is observed. It is found that there is a trade-off between over-controlling the furnace, which results in too sensitive a response to normal flow oscillations, and under-controlling, which results in a lagged response to the fuel change.

15/00248 High-throughput processes for industrially scalable deposition of zinc oxide at atmospheric pressure

Illiberi, A. *et al. Energy Procedia*, 2014, 44, 37–43.

ZnO films have been grown on a moving glass substrate by high temperature (480 °C) chemical vapour deposition (CVD) and low temperature (200 °C) plasma enhanced CVD (PE-CVD) process at atmospheric pressure. Deposition rates above 7 nm/s have been achieved for substrate speeds from 20 to 500 mm/min. The conductivity of the films is enhanced by Al doping of CVD ZnO or by exposure to near-UV radiation of PE-CVD ZnO. Both CVD ZnO:Al and UV-exposed PE-CVD i-ZnO films are highly transparent (>85% in the visible range) and conductive (<15 Ω /sq for a thickness above 1200 nm). ZnO:Al has been used as front electrode in amorphous silicon (a-Si:H) solar cells while i-ZnO has been applied as electrode in CIGS solar cells, achieving an efficiency of 8% and 15.4%, respectively.

15/00249 Improved group search optimization method for solving CHPED in large scale power systems

Hagh, M. T. *et al. Energy Conversion and Management*, 2014, 80, 446–456.

This paper presents an improved heuristic algorithm for solving combined heat and power economic dispatch (CHPED) problem in large-scale power systems, by employing improved group search optimization (GSO) method. The basic deficiency of the original GSO algorithm is the fact that, it gives a near optimal solution rather than an optimal one in a limited runtime period. In this paper, some modifications have been applied to the original GSO in order to improve its searching ability. In this work, a sinusoidal term is employed to consider the valve-point effects and Kron's formula is used in order to consider the transmission losses. Moreover, prohibited operating zones of power-only units are considered. The effectiveness and accuracy of the proposed method for solving the non-linear and non-convex problems is validated by carrying out simulation studies on sample benchmark test cases and three large-scale power systems. Numerical results indicate that proposed method has the better performance in comparison with original GSO and some recently published papers.

15/00250 Industrial excess heat driven post-combustion CCS: the effect of stripper temperature level

Andersson, *et al. International Journal of Greenhouse Gas Control*, 2014, 21, 1–10.

The implementation of post-combustion carbon dioxide capture and storage (CCS) provides an opportunity for the oil refining sector to drastically decrease its CO₂ emissions. Previous studies have shown that the largest cost is the heat supply to the stripper reboiler. When performing CCS at an oil refinery it could therefore prove economically beneficial to utilize the excess heat from refinery processes to

meet this demand for heat. The present study investigates the heat demand in a stripper reboiler at different temperature levels from 120 to 90 °C. At temperatures <120 °C the heat demand increases, but the availability of excess heat also increases. A case study that connects heat demand results with data from an oil refinery shows that if only excess heat is utilized as a heat source, the amount of CO₂ that can be separated is largest when the temperature in the stripper reboiler is 90 °C. If, however, CCS with a capture rate of 85% were applied to the four largest chimneys at the refinery, the external heat demand would be the lowest for the standard temperature of 120 °C.

15/00251 Industry location in Chinese provinces: does energy abundance matter?

Grether, J.-M. *et al. Energy Economics*, 2014, 44, 383–391.

This study identifies the driving factors of manufacturing activity across Chinese provinces with a particular focus on energy endowments. A model of production location is estimated, including both comparative advantage and economic geography determinants. The data set used consists of a panel of 28 Chinese provinces and 12 manufacturing industries over the period 1999–2009. Results confirm the relative importance of energy endowments. It was found that larger energy endowments are significantly correlated with larger production of energy-intensive sectors. Disaggregation across energy carriers shows that coal exhibits the strongest impact. These results are robust across alternatives.

15/00252 Innovative phase change material (PCM) for heat storage for industrial applications

Kenfack, F. and Bauer, M. *Energy Procedia*, 2014, 46, 310–316.

A new phase change material (PCM) based on a salt hydrate which can be incorporated in latent heat storage systems for efficient handling of thermal energy around 100 °C has been prepared. Compared with the pure salt hydrate, the results showed that the newly developed salt hydrate PYCO-PCM-1 is of high thermal stability. The storage capacity of 83.33 kWh m⁻³ for a temperature range $\Delta T = 20$ K, corresponds to about four times the energy which can be stored with the same volume of water. Expanded graphite has been proven as a promising additive for improving the conductivity of PYCO-PCM-1.

15/00253 New experimental system for high pressure and high temperature flashing evaporation experiments

Shao, Y. *et al. Applied Thermal Engineering*, 2014, 66, (1–2), 148–155.

Considering the high pressure and high temperature flash evaporation appearing frequently in industry, an experimental system was designed and built to explore the flash evaporation under high pressure and high temperature that has not been studied very well. This system included a very large chamber that provided enough space for the flash wave to spread and also allowed two large visualization windows on it, so more image information could be obtained. The chamber was designed to have the cylindrical inner shape to satisfy the strength requirements while the outer shape was cubic. Of particular feature was the boiler as the heat system, which was used in the system to heat the water in the chamber. The fibre Bragg grating sensors were used to measure the temperature of the test liquid (water) and a high-speed digital camera is set in front of the visualization window to record the pictures of the flash phenomenon. Finally, a test was carried out to verify this system.

15/00254 Opportunity to use PVT systems for water heating in industry

Hazi, A. *et al. Applied Thermal Engineering*, 2014, 63, (1), 151–157.

This paper presents a technical and economical assessment of the opportunity to use photovoltaic-thermal panels (PVT) systems for water heating in industry. For this purpose, a mathematical model is developed to evaluate the energy parameters and economic indicators according to three variables: solar irradiance, air temperature and water supply temperature. The critical reduced temperature parameter is defined corresponding to the zero difference between the output and input water temperature in the PVT system. The mathematical model developed is used to simulate the operation of such a system under different climatic locations in Romania. Numerical analysis revealed the influence of three variables on the energy parameters and economic indicators. The conclusion is that using a PVT system for water heating in industry is economically attractive, in the climatic conditions of Romania, and the payback period is lower than its lifetime.

15/00255 Overcurrent relay with unconventional curves and its application in industrial power systems

Soria, O. A. *et al. Electric Power Systems Research*, 2014, 110, 113–121.

This paper presents a generalized formulation of an inverse time overcurrent relay that can generate non-conventional inverse time curves. The proposed model considers a variable time dial position as a function of the fault current; the interaction of two dynamics, the digital representation of the movement of the induction disc (such as conventional relays) and the time dial result in time curves that can be

designed for any specific protection coordination problem. The proposed relay does not require more input data than conventional relay, only the fault current in the relay location is required. The proposed model has greater flexibility for the creation of time curves than conventional relay models because it allows the incorporation of independent functions of the time lever that will result in several time curves depending on the defined application criteria. A comparison of the curve fitting between the proposed model and the curve standard model was evaluated using two cases of an industrial power system, for which the non-conventional curves allow the reduction of operation times, mechanical stress and thermal effects. Furthermore, this approach could also prevent damage to the primary equipment.

15/00256 Simultaneous synthesis gas and styrene production in the optimized thermally coupled reactor

Mirvakili, A. *et al. Journal of Natural Gas Science and Engineering*, 2014, 16, 18–20.

Styrene (ST) is one of the most important monomers widely used in the production of polystyrene, resins, and elastomers. In this study, a thermally coupled reactor (TCR) has been suggested for styrene production in which styrene production reaction takes place in the endothermic side and a new process concept called methane tri-reforming for synthesis gas production (H_2 and CO) is considered in the exothermic side of the reactor. The heat generated in the exothermic side is transferred to the endothermic section. A one dimensional steady state model has been developed for thermally coupled reactor. Furthermore the optimization of TCR has been carried out in order to maximize the conversion of ethylbenzene (EB) and methane by Differential evolution (DE) method. Results of the optimization prove that in addition to saving energy, the production of styrene exceeds in the optimized thermally coupled reactor (OTCR) with respect to the conventional reactor (CR) about 5%. Additionally, high values of CO and H_2 yield, 2% and 3%, respectively, could be achieved in the exothermic side.

15/00257 Socio-technical barriers to the use of energy-efficient timber drying technology in New Zealand

Bell, M. *et al. Energy Policy*, 2014, 67, 747–755.

This study of industrial energy behaviours identifies barriers to the use of energy-efficient drying technology in the New Zealand timber industry, and explores these barriers through the 'energy cultures' lens. Vented kiln dryers were preferred by larger firms and heat pump kiln dryers were used by smaller firms. Although few firms could specify all their costs, no significant differences were found in the average operating costs, drying costs or commercial success of the larger and smaller firms. It was found that socio-technical barriers create 'energy cultures' at the level of both the firm and the sector, supporting the dominance of vented kiln dryers. The prevailing technologies, practices and norms at the sector level strongly support vented kilns, the status quo being embedded in the socio-technical context, hindering technological learning, improved energy efficiency and innovation. Influential stakeholders in the industry were thus part of, and locked into, the industry-wide energy culture, and were not in a position to effect change. It was concluded that actors external to the prevailing industry energy culture need to leverage change in the industry norms, practices and/or technologies in order to reap the advantages of energy-efficient drying technology, assist its continued evolution and avoid the risks of path-dependency.

15/00258 The multiple role of energy storage in the industrial sector: evidence from a Greek industrial facility

Zafirakis, D. *et al. Energy Procedia*, 2014, 46, 178–185.

According to European Union Directive 2012/27/EU concerning energy efficiency, emphasis should be given on the promotion of best energy practices in the industrial sector. Acknowledging this, the objective of the current study is to demonstrate the multiple role of industrial energy storage. More precisely, load management and arbitrage strategies are investigated through the development of a simulation algorithm. Considering also the characteristics of the Greek electricity market, results obtained from the application of the proposed algorithm to a Greek industrial facility designate the need for revising current electricity price rates and/or developing novel financial tools for the support of industrial energy storage.

15/00259 Theoretical analysis of free-surface film flow on the rotary granulating disk in waste heat recovery process of molten slag

Wang, D. *et al. Applied Thermal Engineering*, 2014, 63, (1), 387–395.

This paper proposed a simple theoretical model to characterize the continuous free-surface film flow on the rotary disk in waste heat recovery process of molten slag by the method of order of magnitude analysis. Liquid film thickness, mean radial velocity and degree of tangential slippage have been analysed based on the proposed model. The model indicates that the free-surface film flow on the rotary disk is governed primarily by the balance between Coriolis and centrifugal

forces and viscous drag after the hydraulic jump. The inertia force contributes primarily nearby the centre of the rotary disk. It is revealed that the liquid film thickness distribution on a rotary disk is mainly determined by the volume flow rate, kinematic viscosity of molten slag and the rotational speed of disk. Compared with the existing results and computational fluid dynamics simulation data, the model shows good performance. As indicated by the computational fluid dynamic simulation results, the hydraulic jump region has no influence on the liquid flow after the hydraulic jump, hence has none effect on the granulation performance of molten slag.

15/00260 Thermodynamic and exergoeconomic analysis of a cement plant: part I – methodology

Atmaca, A. and Yumrutaş, R. *Energy Conversion and Management*, 2014, 79, 790–798.

The energy, exergy and exergoeconomic analysis of a cement factory has been studied within two parts. This paper is the first part of the study which includes the thermodynamic and exergoeconomic methodology and formulations developed for such a comprehensive and detailed analysis. The second part of this study is about the application of the developed formulation which considers an actual cement plant located in Gaziantep, Turkey. The energy consumption by the cement industry is about 5% of the total global industrial energy consumption. It is also one of the world's largest industrial sources of CO₂ emissions. In this paper, a cement plant is considered with all main manufacturing units. Mass, energy, and exergy balances are applied to each system. The first and second law efficiencies based on the energy and exergy analysis and performance assessment parameters are defined for the entire cement plant. The formulations for the cost of products, and cost formation and allocation within the system are developed based on exergoeconomic analysis. In order to obtain the optimal marketing price of cement and to decrease specific energy consumption of the whole plant, the cost analysis formulated here have substantial importance.

15/00261 Thermodynamic and exergoeconomic analysis of a cement plant: part II – application

Atmaca, A. and Yumrutaş, R. *Energy Conversion and Management*, 2014, 79, 799–808.

This paper is the second part of a study on the thermodynamic and exergoeconomic analysis of a cement plant. In the first part, the thermodynamic and exergoeconomic formulations and procedure for such a comprehensive analysis are provided while this paper provides an application of the developed formulation that considers an actual cement plant located in Gaziantep, Turkey. The overall energy and exergy efficiencies of the plant are found to be 59.37% and 38.99%, respectively. The exergy destructions, exergetic cost allocations and various exergoeconomic performance parameters are determined by using the exergoeconomic analysis based on specific exergy costing method for the entire plant and its components. The specific unit exergetic cost of the farine, clinker and cement produced by the cement plant are calculated to be US\$43.77/GJ, \$133.72/GJ and \$180.50/GJ, respectively. The specific manufacturing costs of farine, clinker and cement are found to be \$3.8/ton, \$33.11/ton and \$41.84/ton, respectively.

15/00262 Thermodynamic performance assessment of a small size CCHP (combined cooling heating and power) system with numerical models

Jannelli, E. *et al. Energy*, 2014, 65, 240–249.

This study evaluates the performance of a small-size combined cooling heating and power (CCHP) system based on the integration of 20 kW Lombardini diesel engine and a double effect water–LiBr absorption chiller. This integrated system has been designed to produce both hot water, by recovering heat from the engine cooling system, and chilled water, by recovering heat from the engine exhaust gases (the exhaust gases are sent to the fired-combustor of the absorption chiller). The analysis has been conducted by using numerical simulations: the engine and the absorption chiller have been modelled by means of 0–1-dimensional and thermochemical models, respectively, and the validation procedure has been performed by using the available operating data. The system performance has been calculated by introducing some performance parameters that have allowed: (i) to estimate the efficiency of the primary energy conversion into useful energy (energy utilization factor), (ii) to consider the quality difference between cool/heat and work and among heats at different temperatures (exergy utilization); and (iii) to evaluate the primary energy saving with respect to the separate production of the same energy fluxes (trigeneration primary energy saving).

15/00263 Top management and the adoption of energy efficiency practices: evidence from small and medium-sized manufacturing firms in the US

Blass, V. *et al. Energy*, 2014, 65, 560–571.

Barriers to energy efficiency have been extensively discussed in the energy literature, but little is known about positive drivers. This paper investigates the role of top managers and more specifically of top operations managers on the adoption of energy-efficiency practices, based on 5779 energy efficiency recommendations made to 752 small- and medium-sized manufacturing firms under the US Department of Energy's Industrial Assessment Centers (IACs) programme, through which teams of students and faculty members from engineering schools provide free energy assessments. Top operations managers possess knowledge of production processes, for maximizing the effective manufacture and distribution of goods. It was found that their involvement significantly increases the adoption of energy-efficiency initiatives, while involvement of general top managers without an operational role has little or no effect. Involvement of top operations managers increases the percentage of recommended energy savings that are implemented by 13.4% on average and increases the probability of adoption of more disruptive individual recommendations related to process and equipment change from 31% to 44%. The findings imply that, in order to advance energy efficiency in small and medium enterprises, it may be advisable to target managers who are sufficiently senior but still in a clearly operationally focused position.

15/00264 Voltage sags in the automotive industry: analysis and solutions

Di Fazio, A. R. *et al. Electric Power Systems Research*, 2014, 110, 25–30.

The objective of this paper is to present the actual solutions used to solve process-interruption problems caused by voltage sags in a large automotive industry. A brief description of the industrial process is presented to focus attention on only the production units that are most vulnerable to voltage sags. Then, the industry's experience with interrupted production is reported and analysed. A two-step procedure is proposed to evaluate the equipment that should be targeted for the application of compensating solutions. In applying this procedure, a criteria based on the Kaizen approach is used to select both the areas for intervention and the types of compensating solutions. The results consist of adequate compensating devices, characterized by very low costs in comparison to the costs associated with lost production, due to the negative effects of voltage sags. The effectiveness of the proposed solutions was proven by an *ex post* analysis that lasted for one year after the intervention. The main conclusion of the study provides evidence that supports the real possibility of solving extensive voltage sag problems in large industries using economical devices. The practical implications of the method were demonstrated by extending it successfully to additional production units in the same factory.

15/00265 Wetting kinetics, kinematics and heat transfer characteristics of Pongamia pinnata vegetable oil for industrial heat treatment

Ramesh, G. and Prabhu, K. N. *Applied Thermal Engineering*, 2014, 65, (1–2), 433–446.

The suitability of *Pongamia pinnata* vegetable oil as cooling medium for quench heat treatment was investigated. Wetting kinetics, kinematics and heat transfer characteristics of pongamia oil during immersion quenching of hot Inconel probe were determined and compared with palm and mineral oils. A comparison of the relaxation of contact angle indicated early attainment of equilibrium contact angle for pongamia oil droplet on Inconel substrate. The equilibrium contact angle value of pongamia oil was in between mineral and palm oils. However, the spreading kinetics was faster with pongamia oil. Pongamia oil showed the formation of a stable vapour film on the probe surface during quenching. This phenomenon was not observed in palm oil and other vegetable oils reported in literature. *P. pinnata* oil exhibits uniform nature of wetting front, intermediate rewetting temperature and less variations in rewetting temperatures during quenching. The hardening power of pongamia oil was higher than palm and mineral oils and the cooling of the probe was more uniform during quenching in pongamia oil. The heat transfer characteristics of pongamia oil were found to be superior to palm and mineral oils after film/transition boiling. Pongamia oil showed lower heat transfer but more uniform cooling during film boiling.

New shape-stabilized phase change materials (PCMs) with a positive temperature coefficient (PTC) effect were prepared in this paper. The materials were prepared by adding graphite powder (GP) to the paraffin/low density polyethylene (LDPE) composite and the PTC characteristic was found by adjusting the component ratio of the material. Then the physical structures and thermal properties of the materials were investigated and the effect of various GP mass fractions and paraffin/LDPE mass proportions on the PTC behaviour of the materials was studied experimentally. The results showed that the switching temperature of the materials was about 25°C (room temperature) which approached to the first phase change temperature of paraffin dispersed in the materials. The PTC behaviour of the materials was the best when the GP mass fraction and the mass proportion of LDPE/paraffin were 40wt% and 30:70, respectively. Furthermore, the negative temperature coefficient effect of the materials could be eliminated effectively with heat treatment. This new kind of material is different from the former PTC materials which the switching temperatures focus on high temperature ranges. It makes up for the defect of previous materials that the switching temperatures only range in high temperature rather than room temperature and provides a potential means for the thermal control of the electronic devices or other room temperature thermal control applications.

15/00267 A novel method for finding the optimal heat storage tank capacity for a cogeneration power plant

Katulić, S. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 530–538.

The introduction of a heat storage tank (HST) into a cogeneration power plant was considered in this paper. The power plant investigated consisted of multiple power production units and operated in a two-tariff electricity pricing market. The HST tank capacity was optimized for maximum profits with and without consideration of the investment costs. When the investment costs were included in the optimization, the optimal HST capacity was nearly halved. Optimal sizing of the HST using heat consumption data from prior years requires over one thousand variables in the mathematical model. A novel method was proposed to drastically reduce the number of variables and find the optimal HST capacity using existing optimization algorithms on a typical computer. The results show that introduction of an HST to electrical and thermal energy generation can increase profits and thermal production capacity of the combined cycle power plant.

15/00268 Cryogenic energy storage characteristics of a packed bed at different pressures

Chai, L. *et al. Applied Thermal Engineering*, 2014, 63, (1), 439–446.

A packed bed cryogenic energy regenerator is investigated for use in a cryogenic energy storage (CES) system. With liquid nitrogen used as the working fluid, the cryogenic energy storage characteristics of the packed bed are investigated at pressures of 0.1 and 6.5 MPa. The packed column is 1500 mm in height with a 345 mm inner diameter, and is made of 16-mm thick stainless steel. Granite pebbles about 9 mm in size are used as the medium for energy storage. The transient axial and radial temperature distributions of the packed bed were measured, and the results show that the transient temperature axial distribution exhibits a typical thermocline behaviour at both low and high pressures. The temperature distribution does however vary significantly at the different pressures.

15/00269 Determining the thermal conductivity of liquids using the transient hot disk method. Part I: establishing transient thermal-fluid constraints

Warzoha, R. J. and Fleischer, A. S. *International Journal of Heat and Mass Transfer*, 2014, 71, 779–789.

Methods to determine the thermal conductivity of liquids have come under increased scrutiny recently due to their relative importance in determining the precise physical mechanisms responsible for heat flow in different materials and at multiple length scales. In transient-based systems, one important but often overlooked parameter is the onset of natural convection. In the first part of this study, the transient effects of natural convection are analysed numerically for a relatively new transient thermal characterization system (transient hot disk) in order to determine when they begin to affect the calculation of a surrounding fluid's thermal conductivity. A comprehensive analysis of the effect of a fluid's pertinent thermophysical properties, Rayleigh number and Prandtl number on the sensor temperature response during testing is completed. Subsequently, a correlation is developed to determine the onset of natural convection during testing for fluids having a wide range of Prandtl numbers. The solution is verified using experimentation with multiple fluids having known, temperature-dependent volumetric heat capacities. The correlation is used as part of a new method to accurately calculate the thermal conductivity of different Newtonian fluids in part II of this study.

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15/00266 A new kind of shape-stabilized PCMs with positive temperature coefficient (PTC) effect

Cheng, W.-l. *et al. Energy Conversion and Management*, 2014, 79, 470–476.

15/00270 Determining the thermal conductivity of liquids using the transient hot disk method. Part II: establishing an accurate and repeatable experimental methodology

Warzoha, R. J. and Fleischer, A. S. *International Journal of Heat and Mass Transfer*, 2014, 71, 790–807.

In this study, the accuracy of the conventional method that is employed to determine the thermal conductivity of fluids with the transient plane source (TPS) technique is evaluated experimentally using six different fluids. It was found that the accuracy of this method is insufficient for calculating the thermal conductivity of fluids due to: (1) the technique's inability to resolve the volumetric heat capacity in close proximity to the sensor, leading to highly erroneous calculations of thermal conductivity at early time scales, and (2) the lack of any means to predict whether the onset of natural convection will have an effect during testing. As a result, a new method is developed that utilizes the known volumetric heat capacity of a fluid and the equation used to predict the onset of natural convection that was developed in part I of this study, which is published separately. Results suggest that this new method yields highly accurate calculations for the thermal conductivity of fluids (within 5.6% of values reported in the literature) over a wide range of Prandtl number ($Pr = 0.7$ –11,000) and temperature.

15/00271 Discussion on the applicability of entropy generation minimization and entransy theory to the evaluation of thermodynamic performance for heat pump systems

Cheng, X. T. and Liang, X. G. *Energy Conversion and Management*, 2014, 80, 238–242.

Based on the entropy generation minimization and entransy theory, this study considers the applicability of the concepts of entropy generation rate, entropy generation number, revised entropy generation number, exergy efficiency, entransy increase rate, entransy increase coefficient and entransy efficiency to the analyses of heat pump systems in this paper. The theoretical analyses show that all the concepts except for the entransy increase rate decrease monotonically with increasing coefficient of performance (COP), while only the entransy increase rate increases monotonically with increasing heat flow pumped into the high temperature heat sink. It is shown that the entransy increase rate is not as convenient as the other concepts for the COP analyses, while it is suitable for the analyses of the heat flow into the high temperature heat sources. Some numerical examples are also presented, and the results have verified the theoretical analyses. Therefore, the applicability of entropy generation minimization and entransy theory to the analyses of heat pump systems is conditional, depending on the design objectives.

15/00272 Drying modelling and experimentation of Assam black tea (*Camellia sinensis*) with producer gas as a fuel

Dutta, P. P. and Baruah, D. C. *Applied Thermal Engineering*, 2014, 63, (2), 495–502.

Thin layer drying kinetics of fermented tea (*Camellia sinensis*) was investigated at air temperatures (80, 90, 100, 110°C) and velocities (0.50, 0.65 and 0.75 m s⁻¹) using a producer gas furnace tea dryer. The tea samples weight, dry and wet bulb temperatures and air velocities were recorded continuously during each experiment. The black tea drying data were fitted to different semi-theoretical models such as Lewis, Page, Modified Page, Henderson and Pabis and Two Term, etc. The modified Page model gave better prediction of thin layer drying kinetics of black tea followed by Lewis model. The diffusivity constant ($D_o = 0.746 \times 10^{-3} \text{ m}^2 \text{ s}^{-1}$) and activation energy ($E_a = 52.104 \text{ kJ mol}^{-1}$) were computed from linear regression analysis. The modified Page model gave drying rate constant ($k = 25.91 \times 10^{-4} \text{ s}^{-1}$) and exponent ($n = 1$) at 100°C air temperature. Both air temperatures and velocities have influence to enhance drying rate constant (k) and exponent (n) in Page and Modified Page models. The energy consumption was found as 19.01 MJ kg⁻¹ of made tea (3% w.b.) based on calorific value of producer gas (HHV = 4.39 MJ N m⁻³). Specific energy consumption of the dryer was approximately 6.274 MJ kg⁻¹ of water removed.

15/00273 Effective reflectivity and heat generation in sucrose and PMMA mixtures

Paz Gutierrez, M. and Zohdi, T. I. *Energy and Buildings*, 2014, 71, 95–103.

Recent efforts in the construction sector to develop panels made of agricultural waste and polymer mixtures are becoming more frequent. These panels are usually developed in pursuit of low embodied energy, biodegradability and energy efficiency. Poly(methyl methacrylate) (PMMA)'s transparency and structural advantages over other thermoplastics is making this material progressively more common in façades. While advances in PMMA's recyclability are under development, the process still presents multiple challenges regarding environmental efficiency and resulting structural integrity. It is important, therefore, to establish mixtures where PMMA's structural advantages are balanced with low carbon emission substrates, such as agricultural wastes. Typically, agricultural waste in architectural panels is used for

structural reinforcement (i.e. fibres). However, agro-derived materials such as sucrose have additional and/or alternative potentials in construction applications. Sucrose's unique optical properties can be implemented for light and thermal control. Additionally, since the energy losses of buildings concentrate in the envelopes another major challenge of cladding substrates pertains to how the façade material can improve energy efficiency, i.e. acting as thermal mass while providing light transmission control avoiding conditions such as glare. Façade materials that can minimize environmental impact while supporting energy savings and appropriate natural light conditions bear strong potential for advancing sustainable building technologies. This analysis provides an expression for the overall reflectivity of combinations of sucrose and PMMA, as well as, estimates of the thermal heating rate, as a function of the relative volume fractions and material properties.

15/00274 Experimental and computational studies on a steam jet refrigeration system with constant area and variable area ejectors

Chandra, V. V. and Ahmed, M. R. *Energy Conversion and Management*, 2014, 79, 377–386.

This paper first presents the results from an experimental study of a conventional steam jet ejector refrigeration system and compares the performance with the computational fluid dynamics results of the same. Secondly, it describes a method of developing a variable area supersonic ejector and presents experimental results of the operating performance of the variable area ejector over the same operating conditions. The two ejectors were experimentally tested for boiler temperatures below 120°C and an evaporator temperature below 15°C. It was found that the steam jet refrigeration system can operate with stability at low boiler temperatures of around 90°C and supersonic ejector can enhance the performance of the refrigeration system by eliminating the shock from the ejector.

15/00275 Experimental assessment of position of macro encapsulated phase change material in concrete walls on indoor temperatures and humidity levels

Shi, X. *et al. Energy and Buildings*, 2014, 71, 80–87.

This paper presents the results of experimental investigation on macro-encapsulated phase change material (PCM) incorporated in concrete walls of room models in real conditions. The focus of this study was to evaluate the effect of positions (externally bonded, laminated within and internally bonded) of macro-encapsulated PCM in concrete walls on indoor temperatures and humidity levels of room models. Experimental results indicated that PCM models could adjust the indoor temperature and humidity levels, however, its effectiveness was found to be greatly dependent on the position of PCM in concrete walls. The model with PCM laminated within the concrete walls showed the best temperature control and was effective in reducing the maximum temperature by up to 4°C. Whereas, the model with PCM placed on the inner side of concrete walls showed the best humidity control and reduced the relative humidity by 16% more than the control model. Therefore, it can be concluded that PCM models are thermally efficient and by reducing the relative humidity they provide comfortable and healthy indoor environment. Moreover, it is shown that the application of PCM in public housing flat of Hong Kong is economically visible with a recovery period of 11 years.

15/00276 Experimental investigation of energy and exergy performance of short term adsorption heat storage for residential application

Li, G. *et al. Energy*, 2014, 65, 675–691.

Energy and exergy performance of adsorption storage system was studied experimentally for residential application. A fin-coated heat exchanger was adopted for a sorption bed to quicken the charging process. When the regeneration temperature was 70°C, ambient temperature was 30°C, heat transfer fluid (HTF) inlet temperature for the adsorption bed was 30°C, results showed that the heat energy storage density (ESD) was approximately 805 kJ/kg with the energy efficiency approximately 96%. The exergy efficiency was 26.7% and the loading difference was 0.164. In this study the mass flow rate of the adsorption bed affected more on the storage performance than that of the desorption bed. As the mass flow rate was increased, the ESD increased while the exergy efficiency decreased due to the larger exergy destruction caused by pressure drop. Increasing regeneration temperature and decreasing adsorption temperature could make the ESD and energy efficiency increased, but the exergy efficiency decreased. As ambient temperature was increased, total ESD and energy efficiency increased, and overall exergy efficiency decreased. A larger loading difference could be achieved with increasing the adsorption bed HTF mass flow rate, regeneration temperature, and inlet temperature of HTF for the evaporator, or decreasing inlet temperature of HTF for the adsorption bed.

15/00277 Experimental study of the thermal-energy performance of an insulated vegetal façade under summer conditions in a continental Mediterranean climate

Olivieri, F. *et al. Building and Environment*, 2014, 77, 61–76.
The use of vegetal systems in façades affects the reduction of the buildings' energy demand, the attenuation of the urban heat island (UHI) and the filtration of pollutants present in the air. Even so, up to now the knowledge about the effect of this type of systems on the thermal performance of insulated façades is limited. This article presents the results of an experimental study carried out in a vegetal façade located in a continental Mediterranean climate zone. The objective is to study the effect of a vegetal finishing, formed by plants and substrate, on the thermal-energy performance of an insulated façade under summer conditions. To this effect, the thermal data obtained from two full-scale experimental mock-ups of the same dimensions and composition of the enclosure and only different in the south façade's enclosure where one incorporates a vegetation layer are compared and analysed. The results show that, in spite of the high thermal resistance of the enclosure, the effect of the vegetation is very positive, particularly in the warmer hours of the day. Therefore, vegetal façades can be used as a passive cooling strategy, reducing the consumption of energy for refrigeration and improving the comfort conditions of the users.

15/00278 Measurement of thermal diffusivity of depleted uranium metal microspheres

Humrickhouse-Helmreich, C. J. *et al. Journal of Nuclear Materials*, 2014, 446, (1–3), 100–105.

The high void space of nuclear fuels composed of homogeneous uranium metal microspheres may allow them to achieve ultra-high burn-up by accommodating fuel swelling and reducing fuel/cladding interactions; however, the relatively low thermal conductivity of microsphere nuclear fuels may limit their application. To support the development of microsphere nuclear fuels, an apparatus was designed in a glovebox and used to measure the apparent thermal diffusivity of a packed bed of depleted uranium (DU) microspheres with argon fill in the void spaces. The developed crucible heater test assembly (CHTA) recorded radial temperature changes due to an initial heat pulse from a central thin-diameter cartridge heater. Using thermocouple positions and time-temperature data, the apparent thermal diffusivity was calculated. The thermal conductivity of the DU microspheres was calculated based on the thermal diffusivity from the CHTA, known material densities and specific heat capacities, and an assumed 70% packing density based on prior measurements. Results indicate that DU metal microspheres have very low thermal conductivity, relative to solid uranium metal, and rapidly form an oxidation layer even in a low oxygen environment. At 500 °C, the thermal conductivity of the DU metal microsphere bed was 0.431 ± 0.0560 W/m-K compared to the literature value of approximately 32 W/m-K for solid uranium metal.

15/00279 Modeling performance of multi-component fibrous insulations against conductive and radiative heat transfer

Arambakam, R. *et al. International Journal of Heat and Mass Transfer*, 2014, 71, 341–348.

This study presents a simulation methodology for studying heat transfer in multi-component fibrous media. The simulation method is designed for high-porosity insulation media with air as the interstitial fluid where conduction through the solid structure is minimal. The resistance of fibrous media to radiative heat was obtained via a simulation method that incorporates both the microscale (fibre-level) and macroscale (media-level) properties of the constituent materials. This information was then combined with that obtained analytically for the conduction heat transfer through the media. The method presented here allows one to obtain quantitative predictions for the performance of media made up of different combinations of fibres with different materials or dimensions. For validation purposes, the experiment of Houston and Korpela conducted for glass fibre insulations, was simulated and good agreement was observed between the measurements and predictions. For further demonstration, insulation media made up of glass and mineral wools fibres with different mass fractions and fibre diameters were simulated in blend and layered configurations and compared with each other. It was found that layered and blended fibrous multi-component insulations exhibit similar performance. It was also found that the stacking sequence does not affect the thermal resistance of layered media for the range of parameters studied here, in agreement with previous studies.

15/00280 Nano-encapsulated organic phase change material based on copolymer nanocomposites for thermal energy storage

Tumirah, K. *et al. Energy*, 2014, 66, 881–890.
This study deals with fabrication, physico-chemical characterizations and thermal properties of n-octadecane nanocapsules as organic phase change materials (PCM) for thermal energy storage (TES). Nano-

encapsulated organic PCM was fabricated by encapsulation of n-octadecane as a core with styrene (St)-methylmethacrylate (MMA) copolymer shell using a mini-emulsion *in situ* polymerization method. The influence of St/MMA and n-octadecane/copolymer mass ratio on the encapsulation processes, physico-chemical and thermal properties of the resulting nanocapsules has been studied systematically. Differential scanning calorimeter analysis indicated that the n-octadecane in the nanocapsules form melts at 29.5 °C and crystallize at 24.6 °C. N-octadecane nanocapsules has an enthalpy of 107.9 and 104.9 Jg⁻¹ for melting and crystallization, respectively. Thermogravimetric analysis thermograms showed that the nano-encapsulated organic PCM degraded in two distinguishable steps and has a good chemical stability. The thermal cycling test of the nanocapsules was carried out for 360 heating/cooling cycles and indicates that the developed nanomaterial has good chemical stability and thermal reliability. Based on all the results obtained, it can be concluded that n-octadecane/St-MMA nanocapsules have potential for thermal energy storage for buildings and other applications.

15/00281 Numerical study on hybrid heat pump systems in existing buildings

Klein, K. *et al. Energy and Buildings*, 2014, 69, 193–201.

Air–water heat pumps suffer from reduced thermal output and poor efficiency in cold conditions. As a consequence, they are usually vastly over-dimensioned for most of the heating season. These inherent disadvantages are largely mitigated in hybrid systems, in which a second heat generator provides heating support when required. In this work, a hybrid heat pump system for existing buildings consisting of a retrofitted air–water heat pump and a gas boiler is modelled and examined in full-year dynamic numerical simulations. It is benchmarked with comparable monovalent systems for a 1970s' single family home as well as a renovated variant of the same building. The nominal thermal output of the air–water heat pump as well as the volume of the buffer storage tank are varied in order to study their impact on system performance. With the renovated building model, significantly higher efficiencies (seasonal performance factor of 3.88 vs 3.34) and load factors (0.57 vs 0.36) are achieved. Medium-sized heat pumps attain the highest seasonal performance factor values, the reason for which is rooted in the alternative-parallel bivalent operation scheme and the dependency of the bivalence point on the heat pump characteristic. The volume of the buffer storage tank has very limited impact on system performance.

15/00282 Object-oriented modeling for the transient response simulation of multi-pass shell-and-tube heat exchangers as applied in active indirect thermal energy storage systems for concentrated solar power

Zaversky, F. *et al. Energy*, 2014, 65, 647–664.

This work focuses on the transient numerical modelling of multi-pass shell-and-tube heat exchangers that apply single-phase fluids. A one-dimensional modelling approach is used for the heat exchanger ducts. The governing partial differential equations are solved numerically by applying the finite volume method. In particular, the commonly applied cell-method is used, which is presented in a flexible, intuitive and simulation-platform-independent way. Simulation results are checked for consistency by comparing them to theoretical as well as experimental data available in the literature. Subsequently, the presented modelling approach is used for a specific case study, showing the transient behaviour of a typical heat exchanger train configuration currently used at active indirect thermal energy storage systems for concentrated solar power (CSP). Typical process parameters (process gain, dead time and time constant) are given for charging as well as for discharging mode at different heat exchanger loads. Furthermore, transient response simulation results are discussed in detail, providing all used boundary conditions and assumed heat exchanger specifications, thus enabling future model comparison studies. Finally, suitable degrees of discretization are discussed for transient CSP performance simulations on system level, offering a good trade-off between simulation speed and accuracy.

15/00283 On a cool coating for roof clay tiles: development of the prototype and thermal-energy assessment

Pisello, A. L. *et al. Energy Procedia*, 2014, 45, 453–462.

Clay tiles are the most common roof covering in Italian buildings, in particular in traditional residential buildings. Given the important role of the roof characteristics for building energy efficiency and indoor thermal comfort conditions, innovative solutions for improving the thermal-energy performance of such diffused roof element has become a key research issue. In this view, cool roof applications represent an effective solution to this aim. The present work deals with the analysis of innovative coatings for traditional clay tiles, aimed at increasing their 'cooling' potential. Several pigments with the sodium silicate as binder are tested in terms of reflectance and emittance, which mainly determine the cool roof performance. Additionally, the year-round performance of the proposed tile is evaluated when applied to a single

family residential building located in central Italy. The developed cool roof solution is characterized by the same visual appearance of traditional 'natural brick' coloured tiles, while the solar reflectance is higher than natural terracotta tile by 13%. Therefore its thermal performance is optimized in order to reduce the roof overheating and the consequent energy requirement for cooling. Results of dynamic simulation of the case study building show how the proposed tile is able to decrease the number of hours when the indoor operative temperature of the attic is higher than 26 °C by 18%, while the same effect in lowering the indoor temperature below 20 °C in winter is less than 1%. Therefore, the proposed solution could be considered as an interesting strategy for new buildings or for traditional roof retrofitting, without producing any significant architectural impact, even in traditional or historic buildings, where more invasive solutions are too difficult to be implemented.

15/00284 Optimal sizing of a thermoelectric heat pump (THP) for heating energy-efficient buildings

Kim, Y. W. *et al. Energy and Buildings*, 2014, 70, 106–116.

This paper aims to determine the optimal design and operating conditions of an air-to-air thermoelectric heat pump (THP) composed of thermoelectric modules (TEMs) and two heat sinks, coupled to an energy-efficient building. The authors focus on the optimal number of TEMs and the optimal electrical current for three standard cases. The performance is quantified using two different coefficients of performance (COP) definitions: performance of THP only (COP_{HP}) and performance of THP coupled to an energy-efficient building (COP_u). These COP are also studied for both instantaneous and seasonal conditions. It was shown that for each coupling, a range of modules exists, with which the maximum performance of the THP can be approached, by simply adapting the electrical current for each condition. Finally, the seasonal performance COP_{HP}^s/COP_u^s for the French city of Macon is estimated and compared for the three cases considered. The original sizing approach proposed here leads to a slight increase of the COP_{HP}^s/COP_u^s (up to +4%), compared to the classical design based on instantaneous nominal conditions (norm). Moreover, it was shown that the optimal number of modules can be largely reduced (up to –39% for the cases considered) compared to nominal condition method.

15/00285 Parametric study on the performance of double-layered microchannels heat sink

Wu, J. M. *et al. Energy Conversion and Management*, 2014, 80, 550–560.

Microchannel is one of several high-heat-flux removal techniques being used in electronic cooling. Double-layered microchannel heat sink (DL-MCHS) with counter current flow arrangement is found not only to be able to lower the thermal resistance of the heat sink, but also decrease the maximum temperature and streamwise temperature rise on the base surface compared with single-layered microchannel heat sink (SL-MCHS). The present paper numerically investigated the thermal resistance, pumping power and temperature distribution on the base surface of substrate of DL-MCHS in different microchannel parameters and flow conditions, so as to find the complicated relationship between the overall performance of DL-MCHS and its geometric parameters and flow conditions. The numerical results show that the optimal width ratio of DL-MCHS should be increased when the microchannel aspect ratio is increased. The effectiveness of increasing aspect ratio of microchannels on improving the overall performance of DL-MCHS is dependent on the pumping power provided. DL-MCHS with higher aspect ratio and smaller width ratio is suited to the situation when higher pumping power is provided. Compared with the situation with identical inlet velocity being assigned to the bottom and upper microchannels, adjusting the inlet velocity of upper channels to be smaller than that of bottom channels may result in the improvement of the overall performance of DL-MCHS at a given pumping power, especially when the given pumping power is lower. These strategies could be tried in the real application of DL-MCHS.

15/00286 Phase-change-materials as energy source for micro aerial vehicles (MAV)

Lidor, A. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 185–193.

While there are many different challenges in the development of micro-aerial vehicles (MAV), one of the severe limiting factors in terms of weight is the energy storage/power system. Most of the MAVs developed to date are based on electrical motors. In the present study, several potential alternative energy storage/power systems are examined, evaluated for their specific energy and specific power, and compared to electrical batteries and hydrocarbon fuel storage. Analysis of the power and energy requirements of different MAV configurations, suggests that a specific power of 35–60 W/kg for fixed wing MAV and 65–85 W/kg for rotary wing MAV are needed. The required specific energy for a short mission of 20 min is 15–25 Wh/kg for fixed wing MAV and 30–40 Wh/kg for rotary wing MAV. Based on these requirements, a novel phase change material (PCM) open-cycle storage/power system is proposed. It comprises of an open cycle that

uses the ambient temperature as its hot reservoir. Promising initial results, in terms of specific power (45–70 W/kg), specific energy (24–45 Wh/kg) and open-cycle thermodynamic efficiency (22–54%), are presented. Owing to the high potential of the proposed PCM open-cycle, the authors believe that the development of new PCM materials specifically designed for this purpose is highly deserving.

15/00287 Potentials of demand side management using heat pumps with building mass as a thermal storage

Ellerbrok, C. *Energy Procedia*, 2014, 46, 214–219.

Within this work, load-shifting possibilities of heat pumps in residential buildings as well as its influencing and limiting factors are displayed. The intermediate storage is achieved by using the thermal mass of the building so the heat supply can be postponed from the heat demand for a certain period, depending on the characteristics of the building. No additional water storage is considered.

15/00288 Stability analysis of parallel-channel systems under supercritical pressure with heat exchanging

Liu, P. *et al. Annals of Nuclear Energy*, 2014, 69, 267–277.

The flow in the core of supercritical water reactors (SCWRs) experiences drastic change in its thermodynamic properties and transport properties near the pseudo-critical temperature, thus the core flow may be susceptible to density wave oscillation instability, which is a challenge to the system safety and must be studied carefully. This work studies the stability characteristics of parallel-channel systems with heat exchanging, the prototype of which is originated from the thermal-spectrum zone assemblies of a newly designed mixed-spectrum SCWR (SCWR-M). A frequency-domain model has been developed for linear stability analysis, and marginal stability boundaries under several conditions are generated, which indicate that the system normal operational condition is in an absolute stable region. Decreasing the wall thermal conductivity can improve system stability while increasing mass flow is beneficial for the system stability. The system is not very sensitive to the axial power distributions. A one-dimensional time-domain model has also been developed for non-linear analysis, and several transients with mass flow perturbations are calculated. The system marginal stability boundaries calculated by using frequency-domain and time-domain methods are in good agreement with each other. The existence of transitional stable region has been observed. A special case of parallel-channel systems with heat exchanging has been studied and achieved the conclusion that the second eigenvalue should be considered when studying the stability characteristics of complicated systems by using frequency-domain methods.

15/00289 Study on the performance of silica gel dehumidification system with ultrasonic-assisted regeneration

Yao, Y. *et al. Energy*, 2014, 66, 799–809.

A theoretic model is developed to describe the moisture desorption-and-adsorption cycle of silica gel dehumidification system with or without ultrasonic-assisted regeneration. The model has been validated by a series of experiments. The additional moisture removal capacity (AMRC) and the dehumidification coefficient of performance (DCOP) are suggested to illustrate the performance of silica gel dehumidification system with ultrasonic radiation. The effects of ultrasonic-assisted regeneration on the performance of the dehumidification system are investigated with the model under different conditions. Some crucial conclusions have been drawn from the simulation results, e.g. the higher regeneration temperature is conducive to increasing the AMRC; the higher ambient air temperature is conducive to increasing the AMRC and DCOP of the system; the higher ambient air humidity level will result in the bigger AMRC and the lower DCOP of the system; the higher initial moisture ratio of silica gel is in its favour for improving the DCOP, but unfavourable for increasing the AMRC; the optimal regeneration time aiming at the maximum AMRC or DCOP decreases as the regeneration temperature or the air velocity increases. It also increases as the ambient air temperature or humidity or the initial moisture content of silica gel increases.

15/00290 The optimization of mixing ratio of expanded graphite mixed chemical heat storage material for magnesium oxide/water chemical heat pump

Kim, S. T. *et al. Applied Thermal Engineering*, 2014, 66, (1–2), 274–261.

A chemical heat storage composite material (EMC), a mixture of expanded graphite (EG), magnesium hydroxide ($Mg(OH)_2$), and calcium chloride ($CaCl_2$), was developed as a magnesium oxide/water chemical heat pump reactant. The potential of the EMC was confirmed and optimized mixing weight ratio between EG and $Mg(OH)_2$ was suggested in previous study. In this study, the optimization of mixing molar ratio between $Mg(OH)_2$ and $CaCl_2$ for practical application was conducted; total six kinds of EMC mixtures, which have different mixing molar ratio from 0, to 0.01 to 0.20 with optimized mixing weight ratio, were prepared then dehydration and hydration experiments were

carried out. From experimental results, it was confirmed that hydration reacted conversion was increased as increasing amount of CaCl_2 in an EMC and the optimized mixing molar ratio was suggested as mixing molar ratio, α , is 0.1 at mixing weight ratio, n , is 0.8 by considering chemical rate constant and reacted conversion. Hydration under various vapour pressures and temperatures of optimized EMC was also conducted and optimized EMC showed better performance than pure $\text{Mg}(\text{OH})_2$. Finally, the heat output performance of optimized EMC was estimated numerically. In conclusion, optimized EMC performed better on dehydration and hydration than pure $\text{Mg}(\text{OH})_2$ by adding EG, which has high thermal conductivity and large specific surface, and CaCl_2 , which has hydrophilic property.

15/00291 The prediction of heat storage properties by the study of structural effect on organic phase change materials
Hasl, T. and Jiricek, I. *Energy Procedia*, 2014, 46, 301–309.

In this study, organic compounds with different structure were investigated, their latent heats of fusion, melting points and thermal stabilities were measured, and as the final step, trends in structure effect on compound properties were derived. The spectrum of measured compounds is wide including hydrocarbons and their derivatives such as alkanes, alcohols, amines, carboxylic acids, dicarboxylic acids, aromatic hydrocarbons, etc. All measured results were transparently processed and arranged in charts and figures, so derived trends can be easily read. Both, the chain length and the functional group position on the hydrocarbon chain influence the melting point and latent heat value. Different phenomena, such as polymorphism of the alkanes or packing effect on the carboxylic acids, were observed. The melting point appears to increase with the chain length for most of the measured compounds. Such dependence has not been demonstrated in the effect of chain length on the latent heat value. Moreover, this paper is a source of thermodynamic data such as the latent heat of fusion, melting point, supercooling and thermic stability of different organic phase change materials within the melting temperature range between -5 and 80°C .

15/00292 The thermal effect of an innovative cool roof on residential buildings in Italy: results from two years of continuous monitoring

Pisello, A. L. and Cotana, F. *Energy and Buildings*, 2014, 69, 154–164. Cool roofs represent an innovative and relatively inexpensive technique to reduce building energy requirements for cooling and to improve indoor thermal comfort conditions. These applications primarily consist of high-reflectance and high-emissivity coatings or membranes commonly applied to the flat roofs of non-residential buildings located in both hot and mild climates. This paper discusses the possibility of applying an innovative 'cool roof' solution, consisting of a prototype cool clay tile, on a traditional residential building in central Italy to improve the thermal conditions of the indoor environment that is adjacent to the roof. In particular, the results of a 2-year continuous monitoring campaign are presented. The building was monitored for an entire year in the original configuration and for another entire year in the optimized configuration, with the final objective of quantifying both the summer benefits and the winter penalties of such a solution in residential buildings in temperate climate conditions. The year-round analysis shows that the proposed cool roof solution produces a maximum effect of decreasing summer peak indoor overheating of the attic by up to 4.7°C . The corresponding winter maximum overcooling reduction is 1.2°C . These experimental results show that this innovative cool roof solution can be implemented on traditional sloped roofs with a clay tile covering, producing substantial benefits in summer and relatively small penalties in winter for residential buildings, even in temperate climates.

11 ENGINES

Power generation and propulsion, electrical vehicles

15/00293 A reduced mechanism for predicting the ignition timing of a fuel blend of natural-gas and n-heptane in HCCI engine

Bahloul, K. *et al. Energy Conversion and Management*, 2014, 79, 85–96. One of the main challenges associated with homogeneous charge compression ignition (HCCI) combustion engine application is the lack of direct control on ignition timing. One of the solutions to this

problem is mixing two fuels with various properties at a variety of ratios on a cycle-by-cycle basis. In the current study, a reduced mechanism for a fuel blend of natural gas and n-heptane is proposed. The approach is validated for the prediction of ignition timing in the HCCI combustion engine. A single-zone combustion model is used to simulate the HCCI engine. A two-stage reduction process is used to produce two reduced mechanisms of existing semi-detailed GRI-Mech. 3.0 mechanism that contains 53 species and 325 reactions and Golovichev's mechanism consisting of 57 species and 290 reactions for natural gas and n-heptane fuels, respectively. First, the unimportant species and related reactions are identified by employing the directed relation graph with error propagation (DRGEP) reduction method and then, to extend reduction, the principal component analysis (PCA) method is utilized. To evaluate the validity of the reduced mechanism, representative engine combustion parameters such as peak pressure, maximum heat release, and a crank angle of 50° are used. The reduced mechanism of GRI-Mech. 3.0 mechanism, containing 19 species and 39 reactions, and the reduced mechanism of Golovichev's mechanism, consisting of 40 species and 95 reactions, provide good prediction for the mentioned parameters in comparison with those of detailed mechanisms. The combination of the generated reduced mechanisms is used to develop a reaction mechanism for a fuel blend of natural gas/n-heptane. Then, the genetic algorithm is used for optimization of reaction rate constants in the newly generated mechanism. Simulation results agree well with the experimental results under various operating conditions, while maintaining small errors ($<2^\circ$ crank angle) for the mentioned engine combustion parameter.

15/00294 Analysis of reforming gas combustion in internal combustion engine

Brusca, S. *et al. Energy Procedia*, 2014, 45, 899–908.

The present paper deals with the study of the combustion of reforming gas in a small size internal combustion engine (ICE). Therefore, mathematical models of both the reforming process and the ICE were implemented. In particular, steam reforming of glycerol to produce synthesis gas and spark ignition four-stroke ICEs were studied. The reforming process mathematical model was verified using experimental data. Synthesis gas was used to feed the ICE with different syngas and engine configurations. On the basis of the comparison with the experimental results, it is possible to state that the mathematical model is validated. Engine performance and pollutant emission evaluation was carried out using the integrated mathematical models with reference to the engine running on standard commercial fuel. The results highlight a reduction in engine performance and, at the same time a reduction of pollutant emissions in terms of CO and CO_2 .

15/00295 Combustion, performance, emissions and particulate characterization of a methanol-gasoline blend (gasohol) fuelled medium duty spark ignition transportation engine

Agarwal, A. K. *et al. Fuel Processing Technology*, 2014, 121, 16–24.

This paper describes the comparative performance, emissions, combustion characteristics and particulate size-number distribution of 10% and 20% methanol blends (M10 & M20) with gasoline in a medium duty spark ignition transportation engine, typically used in a mid-sized car *vis-à-vis* baseline gasoline. Brake thermal efficiency of methanol blends was higher than gasoline. Methanol-gasoline blends (gasohol) produced lower CO, NO and smoke emissions than gasoline. The combustion characteristics of gasohol blends were found to be almost identical to gasoline. Minor variations in cylinder pressure were observed for gasohol blends compared to gasoline. Heat release rate for gasoline begins to rise earlier than gasohol at the same engine load and also, peaks of heat release rate for gasohol were wider compared to gasoline. With increasing engine load, combustion duration decreased because at higher engine loads, combustion was relatively faster. Combustion duration of gasohol blends was higher than gasoline, suggesting slower heat release from gasohol. This study indicates that methanol and its blends can be a good replacement of gasoline for transportation engines without any hardware modification as well as any additional serious environmental impact.

15/00296 Exergoeconomic, sustainability and environmental damage cost analyses of T56 turboprop engine

Balli, O. and Hepbasli, A. *Energy*, 2014, 64, 582–600.

The main objective of this study is to assess the performance of T56 turboprop engine using the exergoeconomic, sustainability and environmental damage cost analysis methods at different power loadings. The unit exergy cost of the shaft power decreases from $\$76.34/\text{GJ}$ at 75%-mode to $\$58.32/\text{GJ}$ at takeoff-mode due to increasing the shaft power. The unit exergy cost of the kinetic exergy increases $\$599.43/\text{GJ}$ at 75%-mode to $\$666.76/\text{GJ}$ at takeoff-mode because of the unit exergy cost of the exhaust gaseous with the increase in the fuel flow. The sustainability analysis indicates that the gas turbine has the highest sustainability index. Increasing the fuel flow rate raises the environ-

mental pollutants and the environmental damage cost rate. The environmental damage cost rates of the engine are calculated to be \$423.94/h at 75%-mode, \$576.97/h at 100%-mode, \$634.93/h at military-mode and \$665.85/h at takeoff-mode. The total cost rate consists of the sum of the fuel cost, the capital investment cost, the operating and maintenance costs, and the environmental damage cost. The total cost rates of the engine are determined to be \$1702.59/h at 75%-mode, \$2100.26/h at 100%-mode, \$2220.42/h at military-mode and \$2284.50/h at takeoff-mode.

15/00297 Flow decomposition methods applied to the flow in an IC engine manifold

Sakowitz, A. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 57–65. Large eddy simulation (LES) of the flow and mixing in an engine manifold of a six-cylinder diesel internal combustion (IC) engine is carried out. Proper orthogonal decomposition (POD) and dynamical mode decomposition (DMD) are applied to sets of LES data from these computations. The engine manifold under consideration includes a pipe-junction used for exhaust gas recirculation (EGR). The methods of analysis, POD and DMD, are applied to the velocity field and the exhaust concentration field. It is found that POD facilitates the analysis of the pulsating, complex and turbulent flow field as compared to instantaneous fields. The flow field is dominated by the EGR pulses and their interaction with other pulses originating from the cylinder valves. The maldistribution of EGR concentration among the first cylinder ports can clearly be linked to the EGR pulsations. DMD is able to extract flow structures at certain frequencies. Using these properties of DMD, the motion of the EGR pulses can be extracted and visualized. The combination of LES and flow decomposition is found to give a rational for the interpretation of the flow phenomena, which might facilitate the optimization of engine manifolds in terms of EGR non-uniformity.

15/00298 Modelling and measurement of a moving magnet linear compressor performance

Liang, K. *et al. Energy*, 2014, 66, 487–495.

A novel moving magnet linear compressor with clearance seals and flexure bearings has been designed and constructed. It is suitable for a refrigeration system with a compact heat exchanger, such as would be needed for a computer's central processor unit cooling. The performance of the compressor has been experimentally evaluated with nitrogen and a mathematical model has been developed to evaluate the performance of the linear compressor. The results from the compressor model and the measurements have been compared in terms of cylinder pressure, the ' $P-V$ ' loop, stroke, mass flow rate and shaft power. The cylinder pressure was not measured directly but was derived from the compressor dynamics and the motor magnetic force characteristics. The comparisons indicate that the compressor model is well validated and can be used to study the performance of this type of compressor, to help with design optimization and the identification of key parameters affecting the system transients. The electrical and thermodynamic losses were also investigated, particularly for the design point (stroke of 13 mm and pressure ratio of 3.0), since a full understanding of these can lead to an increase in compressor efficiency.

15/00299 Multi-objective scheduling of electric vehicles in smart distribution system

Zakariazadeh, A. *et al. Energy Conversion and Management*, 2014, 79, 43–53.

When preparing for the widespread adoption of electric vehicles (EVs), an important issue is to use a proper EVs' charging/discharging scheduling model that is able to simultaneously consider economic and environmental goals as well as technical constraints of distribution networks. This paper proposes a multi-objective operational scheduling method for charging/discharging of EVs in a smart distribution system. The proposed multi-objective framework, based on augmented ϵ -constraint method, aims at minimizing the total operational costs and emissions. The vehicle-to-grid capability as well as the actual patterns of drivers are considered in order to generate the Pareto-optimal solutions. The Benders decomposition technique is used in order to solve the proposed optimization model and to convert the large-scale mixed integer non-linear problem into mixed-integer linear programming and non-linear programming problems. The effectiveness of the proposed resources scheduling approach is tested on a 33-bus distribution test system over a 24-h period. The results show that the proposed EVs' charging/discharging method can reduce both of operation cost and air pollutant emissions.

15/00300 Optimal investment and scheduling of distributed energy resources with uncertainty in electric vehicle driving schedules

Cardoso, G. *et al. Energy*, 2014, 64, 17–30.

The large-scale penetration of electric vehicles (EVs) will introduce technical challenges to the distribution grid, but also carries the potential for vehicle-to-grid services. If available in sufficient numbers, EVs can be used as a distributed energy resource (DER) and their presence can influence optimal DER investment and scheduling decisions in microgrids. In this work, a novel EV fleet aggregator model is introduced in a stochastic formulation of DER-CAM, an optimization tool used to address DER investment and scheduling problems. This is used to assess the impact of EV interconnections on optimal DER solutions considering uncertainty in EV driving schedules. Optimization results indicate that EVs can have a significant impact on DER investments, particularly if considering short payback periods. Furthermore, results suggest that uncertainty in driving schedules carries little significance to total energy costs, which is corroborated by results obtained using the stochastic formulation of the problem.

15/00301 Performance of a hydrokinetic energy system using an axial-flux permanent magnet generator

Davila-Vilchis, J. M. and Mishra, R. S. *Energy*, 2014, 65, 631–638.

The high density of water has been an important factor for harnessing kinetic energy from marine current flows, tides, flowing rivers, or other artificial water channels. Thus, new technologies are being developed to generate electricity. A good example is hydrokinetic energy systems, which are devices that extract and convert energy from the motion of flowing water into electricity. Although these non-polluting machines and/or devices are still in their pilot phases, they have been growing as a sustainable source of new electric power generation. In this paper, the performance of a horizontal hydrokinetic energy system with variable-pitch blades using an axial-flux generator is evaluated. Very simple sheet blades have been used to keep the system costs down. The evaluation is based on maximum power extraction and energy conversion efficiency normalized by system costs through a simpler electromechanical design for the hydrokinetic system. Experimental results have demonstrated that the proposed prototype possesses higher efficiency with reduced energy losses and manufacturing costs. It represents a cost-competitive alternative energy for power supply for civilian applications in remote areas or an option for expeditionary applications.

15/00302 Quasi-real-time management of electric vehicles charging

Soares, F. J. *et al. Electric Power Systems Research*, 2014, 108, 293–303.

This work presents a methodology to manage electric vehicles (EVs) charging in quasi-real-time, considering the participation of EV aggregators in electricity markets and the technical restrictions of the electricity grid components, controlled by the distribution system operator. Two methodologies are presented in this paper to manage EV charging, one to be used by the EV aggregators and the other by the distribution system operator (DSO). The methodology developed for the aggregator has as main objective the minimization of the deviation between the energy bought in the market and the energy consumed by EVs. The methodology developed for the DSO allows it to manage the grid and solve operational problems that may appear by controlling EVs charging. A method to generate a synthetic EV data set is used in this work, providing information about EV movement, including the periods when EVs are parked and their energy requirements. This data set is used afterwards to assess the performance of the algorithms developed to manage the EV charging in quasi-real-time.

15/00303 Techno-economic investigation of alternative propulsion plants for ferries and RoRo ships

Livanos, G. A. *et al. Energy Conversion and Management*, 2014, 79, 640–651.

In this paper, the main alternative propulsion plants based on reciprocating internal combustion engines of a ferry or roll on–roll off (RoRo) ship operating in routes that include emission control areas are comparatively assessed. Specifically, a dual fuel engine propulsion plant is compared with a conventional diesel engine plant. For both cases, the installation of a waste heat recovery system, which covers a part of the ship's electric energy demand, is also considered. The ship main dual fuel engines are assumed to operate using liquefied natural gas and a small amount of marine diesel oil (MDO) for initiating combustion, whereas low sulfur MDO was regarded as the fuel for the case of the diesel engine plant. The installation of a selective catalytic reduction after-treatment unit for reducing the NO_x emissions in the case of a diesel engine plant is also taken into account. The propulsion plants were modelled under steady-state conditions, and the simulation results were analysed in order to compare the alternative configurations. Furthermore, the energy efficiency design index (EEDI) values were calculated and the two examined propulsion system cases were compared on EEDI basis. Finally, the life cycle cost for each alternative

propulsion plant was calculated and used for completing an economic evaluation of the dual fuel propulsion plant versus the conventional designs applied in ferries.

15/00304 The Miller cycle effects on improvement of fuel economy in a highly boosted, high compression ratio, direct-injection gasoline engine: EIVC vs. LIVC

Li, T. *et al. Energy Conversion and Management*, 2014, 79, 59–65.

A combination of downsizing, highly boosting and direct injection (DI) is an effective way to improve fuel economy of gasoline engines without the penalties of reduced torque or power output. At high loads, however, knock problem becomes severer when increasing the intake boosting. As a compromise, geometric compression ratio (CR) is usually reduced to mitigate knock, and the improvement of fuel economy is discounted. Application of Miller cycle, which can be realized by either early or late intake valve closing (EIVC or LIVC), has the potential to reduce the effective CR and suppress knock. In this paper, the effects of EIVC and LIVC on the fuel economy of a boosted DI gasoline production engine reformed with a geometric CR of 12.0 are experimentally compared at low and high loads. Compared to the original production engine with CR 9.3, at the high load operation, the brake specific fuel consumption (BSFC) is improved by 4.7% with CR12.0 and LIVC, while the effect of EIVC on improving BSFC is negligibly small. At the low load operation, combined with CR12.0, LIVC and EIVC improve the fuel economy by 6.8% and 7.4%, respectively, compared to the production engine. The mechanism behind the effects of LIVC and EIVC on improving the fuel economy is discussed. These results will be a valuable reference for engine designers and researchers.

Hybrid engine systems

15/00305 A real time energy management strategy for plug-in hybrid electric vehicles based on optimal control theory

Tribioli, L. *et al. Energy Procedia*, 2014, 45, 949–958.

Plug-in hybrid electric vehicles are commonly designed to work in charge depleting/charge sustaining (CD/CS) mode, depleting the battery by driving in only-electrical mode until the state of charge (SoC) reaches its minimum acceptable threshold, and then sustaining the state of charge until the end of the mission, operating as a traditional hybrid vehicle. Nonetheless, a simple application of an optimal control framework suggests a blended discharge strategy, in which the powertrain is operated as to gradually deplete the SoC and reach the lower threshold only at the end of the trip. Such an algorithm has the drawback that the optimal solution can only be reached offline, depending on the *a priori* knowledge of the driving event, making it unsuitable to be implemented online, as it is. The paper presents a methodology to design a heuristic controller, to be used online, based on rules extracted from the analysis of the powertrain behaviour under the optimal control solution. The application is a parallel plug-in vehicle, derived from a re-engineered engine-only driven powertrain, and the optimal problem is solved with the Pontryagin's minimum principle. Results are also compared to the same vehicle in its standard internal combustion engine version, as well as the commonly implemented CD/CS strategy.

15/00306 Cold start and full cycle emissions from a flexible fuel vehicle operating with natural gas, ethanol and gasoline

Martins, A. A. *et al. Journal of Natural Gas Science and Engineering*, 2014, 17, 94–98.

This paper describes a comparative study between the pollutant emissions produced by a spark ignition engine operating with three different fuels: commercial gasoline with 22% of ethanol (E22), compressed natural gas (CNG) and hydrous ethanol. The emission levels of oxides of nitrogen (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), total hydrocarbons (HC), and methane (CH_4) produced by a flexible fuel engine operating according to the US 1975 Federal Test Procedure (FTP 75) were analysed. Tests were performed with a mid-size sedan powered by 1.4-L spark ignition engine on a chassis dynamometer. The results for the cold start tests demonstrate that E22 produced the lowest CO and HC emissions, while CNG produced the lowest NO_x emissions. Considering the full test cycle, CNG emitted the lowest CO, NO_x and CO_2 concentrations, and the lowest fuel consumption. Gasoline presented the lowest emission levels of HC and CH_4 . Ethanol showed the highest fuel consumption and higher pollutant emission levels than the other fuels, except for CO_2 , which was higher than CNG and lower than gasoline.

15/00307 Combined numerical-experimental study of dual fuel diesel engine

Abagnale, C. *et al. Energy Procedia*, 2014, 45, 721–730.

In the present paper, the authors discuss the effect of different fuel ratios on the performance and emission levels of a common rail diesel engine supplied with natural gas and diesel oil. Dual fuel operation is characterized by a diesel pilot injection to start combustion in an intake port premixed natural gas/air mixture. The combined numerical – experimental study of the dual fuel diesel engine that is carried out in this paper aims at the evaluation of the computational fluid dynamics potential to predict the main features of this particular engine operation. The experimental investigations represent a tool for validating such a potential and for highlighting, at the same time, the major problems that arise from the actual engine operation with different natural gas/diesel oil fuel ratios.

15/00308 Experimental investigation of the concomitant injection of gasoline and CNG in a turbocharged spark ignition engine

Movahed, M. M. *et al. Energy Conversion and Management*, 2014, 80, 126–136.

Concomitant injection of gasoline and compressed natural gas (CNG) is a new concept to overcome problems of bi-fuelled spark ignition engines, which operate in single fuel mode, either in gasoline or in CNG mode. This experimental study indicates how some problems of gasoline mode such as retarded ignition timings for knock prevention and rich air–fuel mixture for component protection can be resolved with the concomitant injection of gasoline and CNG. Results clearly show that the concomitant injection improves thermal efficiency compared to gasoline mode. On the other hand, simultaneous injection of gasoline and CNG reduces some problems of CNG mode such as high cylinder pressure and heat loss to the engine coolant. This decreases the stringent requirements for thermal and mechanical strength of the engine components in CNG mode. In addition, it is shown that by modifying the spark advance and air fuel ratio in CNG mode, the engine operation improves in terms of NO_x emissions and maximum in-cylinder pressure as the concomitant injection does. Nevertheless, new requirements such as an intercooler with higher cooling capacity are implied to the engine configuration. Finally, the most important concerns in control strategies of the engine control unit for a vehicle with concomitant injection of gasoline and CNG are discussed.

15/00309 Household demand and willingness to pay for hybrid vehicles

Liu, Y. *Energy Economics*, 2014, 44, 191–197.

This paper quantitatively evaluates consumers' willingness to pay for hybrid vehicles by estimating the demand of hybrid vehicles in the US market. Using micro-level data on consumer purchases of hybrid and non-hybrid vehicles from National Household Travel Survey 2009, this paper formulates a mixed logit model of consumers' vehicle choices. Parameter estimates are then used to evaluate consumers' willingness to pay for hybrids. Results suggest that households' willingness to pay for hybrids ranges from \$963 to \$1718 for different income groups, which is significantly lower than the average price premium (over \$5000) of hybrid vehicles, even when taking the fuel cost savings of hybrid vehicles into consideration. The differences reveal that although the market has shown increasing interest in hybrid vehicles, consumers' valuation of the hybrid feature is still not high enough to compensate for the price premium when they make new purchases. Policy simulations are conducted to examine the effects of raising federal tax incentives on the purchase of hybrid vehicles.

15/00310 Managing operations of plug-in hybrid electric vehicle (PHEV) exchange stations for use with a smart grid

Nurre, S. G. *et al. Energy Policy*, 2014, 67, 364–377.

This study considers a deterministic integer programming model for determining the optimal operations of multiple plug-in hybrid electric vehicle battery exchange stations over time. The operations include the number of batteries to charge, discharge, and exchange at each point in time over a set time horizon. Discharging of batteries back to the power grid, through vehicle-to-grid technology, was allowed. The exchange station's dependence on the power network, transportation network and other exchange stations, was also incorporated. The charging and discharging at these exchange stations led to a greater amount of variability which created a less predictable and flat power generation curve. Three policies were introduced and tested to smooth the power generation curve by balancing its load. Further, tests were conducted evaluating these policies while factoring wind energy into the power generation curve. These computational tests used realistic data and analysis of the results suggested general operating procedures for exchange stations and evaluated the effectiveness of these power flattening policies.

15/00311 Mixing effects of biogas and dimethyl ether (DME) on combustion and emission characteristics of DME fueled high-speed diesel engine

Park, S. H. *et al. Energy*, 2014, 66, 413–422.

The purpose of this investigation is to study the effect of biogas mixing on the combustion and emission characteristics of a dimethyl ether (DME)-fuelled diesel engine. Combustion performance was assessed in terms of combustion pressure, rate of heat release (ROHR), ignition delay, and an indicated mean effective pressure (IMEP). NO_x , soot, HC and CO emissions were also analysed using an emission analyser. An increase in the biogas mixing ratio caused a decrease in the peak combustion pressure, ignition retardation and reduction in the rate of the combustion pressure increase. An increase in the biogas also induced a decrease in the peak value and gradient of the ROHR. Injection and ignition timings showed a linear correlation regardless of biogas mixing ratio when DME was injected toward the piston bowl. At the same injection timing, the increase of biogas caused a decrease in IMEP when DME was injected into the piston bowl. When DME was injected toward the crevice and squish region, IMEP increased as the biogas mixing ratio increased, and IMEP showed a linear correlation with start of ignition. Indicated specific NO_x emissions decreased with the increase in biogas. The soot emissions level was close to zero in all test conditions. However, indicated specific HC and indicated specific CO emissions showed an increasing trend with increasing biogas mixing ratio.

15/00312 Numerical simulation and experimental test of dual fuel operated diesel engines

Abagnale, C. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 403–417.

In this paper, the authors discuss the effect of different fuel ratios on the performance and pollutant fractions of a common rail diesel engine supplied with both natural gas (NG) and diesel oil. The study of the dual fuel NG/diesel operation is carried out on a computational fluid dynamics basis, with an engine numerical simulation that includes the gas exchange periods and it aims at a comprehensive analysis of both the combustion development and the pollutant formation under different conditions induced by different choices of the operating parameters and fuel. Preliminary calculations have been performed to individuate the correct setting of some injection models, in order to determine the most appropriate setup of the injection timing when varying the compressed natural gas (CNG) ratio in the fuel blend. The calculations are compared with some experimental data obtained on a light duty direct injection diesel engine at steady state test bench. In particular, a comparison between diesel and dual fuel diesel/CNG operation has been made, in terms of performance and pollutant levels.

15/00313 Studying the feasibility of charging plug-in hybrid electric vehicles using photovoltaic electricity in residential distribution systems

ElNozahy, M. S. and Salama, M. M. A. *Electric Power Systems Research*, 2014, 110, 133–143.

Recently, interest has grown in using photovoltaic (PV) electricity to charge plug-in hybrid electric vehicles (PHEVs). This paper investigates the feasibility of such a charging alternative, from a distribution system performance perspective. To achieve this goal, it is first necessary to determine the resulting aggregated impacts for both technologies when they operate in parallel. Although extensive research has explored the individual impacts of PHEVs and PV electricity on distribution networks, far too little study has been made of the interaction between these two technologies and the resulting aggregated impacts when both operate together. This paper fills this gap by developing a probabilistic Monte Carlo-based benchmark that can be used to assess the resulting impacts when PV arrays are used to charge PHEVs. Finally, the authors compare the resulting aggregated impacts with those resulting when PHEV charging demands are met solely from the medium voltage network, in order to draw conclusions on the feasibility of such a charging alternative. The results reveal that this practice is feasible in short-term, as PV arrays can meet part of the PHEV charging demand and lessen the loading of distribution system equipment, thus reducing the necessity for costly system upgrades. However, in the long-term, PV arrays will not be able to meet the much-increased demand projected with higher PHEV penetration, and so system upgrades will be necessary. These findings are attributed to the weak chronological coincidence between PV array production and PHEV demand.

15/00314 Towards improvement of natural gas-diesel dual fuel mode: an experimental investigation on performance and exhaust emissions

Lounici, M. S. *et al. Energy*, 2014, 64, 200–211.

The use of natural gas in compression ignition engines as supplement to liquid diesel in a dual fuel combustion mode is a promising technique. In this study, the effect of dual fuel operating mode on combustion characteristics, engine performances and pollutants emissions of an existing diesel engine using natural gas as primary fuel and neat diesel as pilot fuel, has been examined. At moderate and relatively high loads, the results show very interesting behaviour of dual fuel operating mode in comparison to conventional diesel, both for engine

performance and emissions. It showed a simultaneous reduction of soot and NO_x species over a large engine operating area. Moreover, it showed the possibility to obtain lower brake specific fuel consumption than conventional diesel engine. However, this mode presents some deficits at low loads, especially concerning unburned hydrocarbons and carbon monoxide emissions. Understanding those deficiencies is a key of such engines improvement. Some suggestions for new measures towards dual fuel mode improvement are deduced.

15/00315 Use of water containing acetone–butanol–ethanol for NO_x -PM (nitrogen oxide-particulate matter) trade-off in the diesel engine fueled with biodiesel

Chang, Y.-C. *et al. Energy*, 2014, 64, 678–687.

Fuel blends that contain biodiesel are known to produce greater emissions of nitrogen oxides (NO_x) in diesel engine exhaust than regular diesel, and this is one of the key barriers to the wider adoption of biodiesel as an alternative fuel. In this study, a water-containing acetone–butanol–ethanol (ABE) solution, which simulates products that are produced from biomass fermentation without dehydration processing, was tested as a biodiesel–diesel blend additive to lower NO_x emissions from diesel engines. The energy efficiency and the particulate matter (PM) and polycyclic aromatic hydrocarbons (PAHs) emissions were investigated and compared under various operating conditions. Although biodiesel had greater NO_x emissions, the blends that contained 25% of the water-containing ABE solution had significantly lower NO_x (4.30–30.7%), PM (10.9–63.1%) and PAH emissions (26.7–67.6%) than the biodiesel–diesel blends and regular diesel, respectively. In addition, the energy efficiency of this new blend was 0.372–7.88% higher with respect to both the biodiesel–diesel blends and regular diesel. Because dehydration and surfactant addition are not necessary, the application of ABE–biodiesel–diesel blends can simplify fuel production processes, reduce energy consumption, and lower pollutant emissions, meaning that the ABE–biodiesel–diesel blend is a promising green fuel.

15/00316 Whole-vehicle modelling of exhaust energy recovery on a diesel-electric hybrid bus

Briggs, I. *et al. Energy*, 2014, 65, 172–181.

Hybrid vehicles can use energy storage systems to disconnect the engine from the driving wheels of the vehicle. This enables the engine to be run closer to its optimum operating condition, but fuel energy is still wasted through the exhaust system as heat. The use of a turbogenerator on the exhaust line addresses this problem by capturing some of the otherwise wasted heat and converting it into useful electrical energy. This paper outlines the work undertaken to model the engine of a diesel–electric hybrid bus, coupled with a hybrid powertrain model which analysed the performance of a hybrid vehicle over a drive-cycle. The distribution of the turbogenerator power was analysed along with the effect on the fuel consumption of the bus. This showed that including the turbogenerator produced a 2.4% reduction in fuel consumption over a typical drive-cycle. The hybrid bus generator was then optimized to improve the performance of the combined vehicle/engine package and the turbogenerator was then shown to offer a 3.0% reduction in fuel consumption. The financial benefits of using the turbogenerator were also considered in terms of fuel savings for operators. For an average bus, a turbogenerator could reduce fuel costs by around £1200 per year.

Transport battery development

15/00317 A real time fuzzy logic power management strategy for a fuel cell vehicle

Hemi, H. *et al. Energy Conversion and Management*, 2014, 80, 63–70.

This paper presents real-time fuzzy logic controller (FLC) approach used to design a power management strategy for a hybrid electric vehicle and to protect the battery from overcharging during the repetitive braking energy accumulation. The fuel cell (FC) and battery (B)/supercapacitor (SC) are the primary and secondary power sources, respectively. This paper analyses and evaluates the performance of the three configurations, FC/B, FC/SC and FC/B/SC during real time driving conditions and unknown driving cycle. The MATLAB/Simulink and SimPowerSystems software packages are used to model the electrical and mechanical elements of hybrid vehicles and implement a fuzzy logic strategy.

15/00318 Assessment of massive integration of photovoltaic system considering rechargeable battery in Japan with high time-resolution optimal power generation mix model

Komiyama, R. and Fujii, Y. *Energy Policy*, 2014, 66, 73–89.

Maximizing renewables in the country's power system has been a key political agenda in Japan after the Fukushima nuclear disaster. This paper investigates the potential of photovoltaic (PV) resources, which could be systematically integrated into the Japanese power system, using a high time-resolution optimal power generation mix model. The model allows us to explicitly consider actual PV and wind output variability in 10-min time resolution for 365 days. Simulation results show that, as PV expands, the growth of PV integration into the grid slows down when the installed PV capacity is more than the scale of the peak demand, although Japan has immense potential of installable PV capacity – equivalent to 40 times of the peak. Secondly, the results imply that a large-scale PV integration potentially decreases the usage ratio of a liquefied natural gas combined cycle (LNGCC) in specific seasons, which is a challenge for utility companies to ensure that LNGCC is used as a profitable compensating generator for PV variability. Finally, a sensitivity analysis on rechargeable battery cost suggests that the reason for suppressing the PV output instead of storing its surplus output by the battery can be attributed to the high battery cost; hence, the improvement of its economic performance is significant to integrate the massive PV energy.

15/00319 Chemically engineered graphene oxide as high performance cathode materials for Li-ion batteries

Ai, W. *et al. Carbon*, 2014, 76, 148–154.

The development of environment-friendly electrode materials is highly desired for the clean and sustainable Li-ion batteries (LIBs) system. Organic cathode materials that involve conducting polymers, organic carbonyl/sulfur compounds are expected to be promising candidates for future LIBs with a concept of 'green and sustainable'. However, their battery performances are relatively worse than that of inorganic counterparts due to their low electronic conductivity and unwanted dissolution reactions occurring in electrolytes. Aimed to alter their performances, this study focuses on the preparation of upgraded organic materials by chemical engineering of graphene oxide (GO) and the systematic study of their electrochemical performance as positive electrodes for LIBs. The obtained decarboxylated GO and carbonylated/hydroxylated GO electrodes show significantly enhanced electrochemical performance compared with that of the GO electrode. The results demonstrate that the manipulation of oxygen functional groups on GO is an effective strategy to greatly improve the Li storage property of GO-based materials for advanced LIBs cathodes.

15/00320 Dynamic operation model of the battery swapping station for EV (electric vehicle) in electricity market

Yang, S. *et al. Energy*, 2014, 65, 544–549.

The battery swapping station (BSS) is a newly proposed mode of supplying power to the electric vehicle (EV). Different from the battery charging station (BCS), the BSS prepares the batteries for EVs in advance and could complete the battery swapping in a short time. The operations designed for the BCS are not appropriate for BSS any longer and the research about BSS is at the early stage. In this paper, a dynamic operation model of BSS in the electricity market is proposed. The new model is based on short-term battery management and includes a mathematical formulation and market strategy. The model was tested in a 24-hour simulation. The results show that the BSS makes decisions in the market environment through tracing the number of batteries in different kinds of states and acquires additional revenue by responding actively to the price fluctuation in the electricity market. The feasibility and the practicability of the model are confirmed.

15/00321 Enhanced sample entropy-based health management of Li-ion battery for electrified vehicles

Hu, X. *et al. Energy*, 2014, 64, 953–960.

This paper discusses an ameliorated sample entropy-based capacity estimator for prognostics and health management of lithium-ion batteries in electrified vehicles. The aging datasets of eight cells with identical chemistry were used. The sample entropy of cell voltage sequence under the well-known hybrid pulse power characterization profile is adopted as the input of the health estimator. The calculated sample entropy and capacity of a reference lithium-ion cell (randomly selected from the eight cells) at three different ambient temperatures are employed as the training data to establish the model by using the least-squares optimization. The performance and robustness of the estimator are validated by means of the degradation datasets from the other seven cells. The associated results indicate that the proposed health management strategy has an average relative error of about 2%.

15/00322 Experimental investigation on the feasibility of heat pipe cooling for HEV/EV lithium-ion battery

Tran, T.-H. *et al. Applied Thermal Engineering*, 2014, 63, (2), 551–558. In this paper, the use of flat heat pipes as an effective and low-energy device to mitigate the temperature of a battery module designed for a HEV application was investigated. For this purpose, nominal heat flux generated by a battery module was reproduced and applied to a flat

heat pipe cooling system. The thermal performance of the flat heat pipe cooling system was compared with that of a conventional heat sink under various cooling conditions and under several inclined positions. The results show that adding heat pipe reduced the thermal resistance of a common heat sink of 30% under natural convection and 20% under low air velocity cooling. Consequently, the cell temperature was kept below 50 °C, which cannot be achieved using heat sink. According to the space allocated for the battery pack in the vehicle, flat heat pipe can be used in vertical or horizontal position. Furthermore, flat heat pipe works efficiently under different grade road conditions. The transient behaviour of the flat heat pipe was also studied under high frequency and large amplitude variable input power. The flat heat pipe was found to handle more efficiently instant increases of the heat flux than the conventional heat sink.

15/00323 Innovative application of ionic liquid to separate Al and cathode materials from spent high-power lithium-ion batteries

Zeng, X. and Li, J. *Journal of Hazardous Materials*, 2014, 271, 50–56.

Because of the increasing number of electric vehicles, there is an urgent need for effective recycling technologies to recapture the significant amount of valuable metals contained in spent lithium-ion batteries (LiBs). Previous studies have indicated, however, that Al and cathode materials were quite difficult to separate due to the strong binding force supplied by the polyvinylidene fluoride (PVDF), which was employed to bind cathode materials and Al foil. This research devoted to seek a new method of melting the PVDF binder with heated ionic liquid (IL) to separate Al foil and cathode materials from the spent high-power LiBs. Theoretical analysis based on Fourier's law was adopted to determine the heat transfer mechanism of cathode material and to examine the relationship between heating temperature and retention time. All the experimental and theoretic results show that peel-off rate of cathode materials from Al foil could reach 99% when major process parameters were controlled at 180 °C heating temperature, 300 rpm agitator rotation, and 25 min retention time. The results further imply that the application of IL for recycling Al foil and cathode materials from spent high-power LiBs is highly efficient, regardless of the application source of the LiBs or the types of cathode material. This study endeavours to make a contribution to an environmentally sound and economically viable solution to the challenge of spent LiB recycling.

15/00324 Integrating electric vehicles as flexible load in unit commitment modeling

Madzharov, D. *et al. Energy*, 2014, 65, 285–294.

Fully electric vehicles (EVs) and plug-in hybrid electric vehicles have attracted much attention in recent years. Towards an increasing share of EVs, their economic feasibility and impact on the electricity distribution have been studied in detail. However, little has been achieved in investigating the impact on the electricity generation systems. This paper presents a mixed-integer linear programming unit commitment model with focus on the effect of EVs on the generation side. The most important advantage of the proposed method is the ability to solve systems with a very large number of EVs. The algorithm is demonstrated on a benchmark system, which has been widely used in the literature and has been used here for all scenarios. It is demonstrated that optimized charging (centrally controlled) is cheaper and allows for higher EV penetration, compared to random charging. Simulations were also run for two scenarios based on the advancement in the charging infrastructure: (1) perfect infrastructure, with opportunity for charging everywhere and (2) moderate infrastructure, where charging is possible only at the owners' homes. In both cases the generation cost increases by 1% for every 10% of additional EV penetration, the modest infrastructure case being slightly more expensive.

15/00325 Management of electric vehicle battery charging in distribution networks with multi-agent systems

Unda, I. G. *et al. Electric Power Systems Research*, 2014, 110, 172–179.

An agent-based control system that manages the battery charging of electric vehicles (EVs) in power distribution networks is presented. The electric vehicle battery charging schedules are calculated according to electricity prices and distribution network technical constraints. The design of the multi-agent system is described and real-time operation of the multi-agent system was demonstrated in a test-bed of a laboratory micro-grid. Four experiments were described and demonstrated in these laboratory facilities, which showed the capabilities of the multi-agent system (MAS) to: (i) manage the EV charging schedules according to electricity prices and network constraints, (ii) adapt the charging schedules after a short term forecast load increase, (iii) reduce EV loading conditions in case of emergency situation, restoring the system to normal operation conditions and (iv) provide active demand services in the form of EV demand reduction if requested by the coordinator agent. The experiments showed the MAS capability to manage the EV battery charging

avoiding overloads in the distribution network assets. A number of issues need to be further elaborated to use this approach: (i) integrating the forecasting tools for accurate predictions on the EVs' arrival rates considering factors such as traffic flows and road congestions, (ii) defining optimal DSO's margins of security to work within technical limits, (iii) adding new functionalities to the MAS including additional users' requirements or dynamic prices schemes to balance its own portfolio and (iv) studying further the optimal scheduling and operational periods' duration, considering latency in communications among agents, as well as memory and processing characteristics of the agents' hosting hardware.

15/00326 Online peak power prediction based on a parameter and state estimator for lithium-ion batteries in electric vehicles

Pei, L. *et al. Energy*, 2014, 66, 766–778.

The goal of this study is to realize real-time predictions of the peak power/state of power (SOP) for lithium-ion batteries in electric vehicles (EVs). To allow the proposed method to be applicable to different temperature and aging conditions, a training-free battery parameter/state estimator is presented based on an equivalent circuit model using a dual extended Kalman filter (DEKF). In this estimator, the model parameters are no longer taken as functions of factors such as state of charge, temperature, and aging; instead, all parameters will be directly estimated under the present conditions, and the impact of the temperature and aging on the battery model will be included in the parameter identification results. Then, the peak power/SOP will be calculated using the estimated results under the given limits. As an improvement to the calculation method, a combined limit of current and voltage is proposed to obtain results that are more reasonable. Additionally, novel verification experiments are designed to provide the true values of the cells' peak power under various operating conditions. The proposed methods are implemented in experiments with LiFePO₄/graphite cells. The validating results demonstrate that the proposed methods have good accuracy and high adaptability.

15/00327 Optimal scheduling of electric vehicles in an intelligent parking lot considering vehicle-to-grid concept and battery condition

Honarmand, M. *et al. Energy*, 2014, 65, 572–579.

The anticipation of a large penetration of electric vehicles (EVs) into the market brings up many technical issues. The power system may put at risk the security and reliability of operation due to uncontrolled EV charging and discharging. It is necessary to carry out intelligent scheduling for charging and discharging of EVs. In this paper, a smart management and scheduling model is proposed for large number of EVs parked in an urban parking lot. The proposed model considered practical constraints such as desired charging electricity price, remaining battery capacity, remaining charging time and age of the battery. The results show that the proposed parking lot energy management system satisfies both financial and technical goals. Moreover, EV owners could earn profit from discharging their vehicles as well as having desired state of charge in the departure time.

from inception to full flashover in all cases using a video camera system. The results from this study argue well for the use of silicone insulation as a barrier in non-uniform field electrode systems regardless of the nature of the environment in which it must operate.

15/00329 Composites of polyethylene glycol (PEG600) with gypsum and natural clay as new kinds of building PCMs for low temperature-thermal energy storage

Sari, A. *Energy and Buildings*, 2014, 69, 184–192.

Composite phase change materials (PCMs) can be used for passive thermal energy storage (TES) applications in buildings under different climatic conditions. From this perspective, two composites of polyethylene glycol (PEG600) with gypsum and natural clay as new kinds of building composite PCMs (BCPCMs) were prepared using vacuum impregnation method. The prepared BCPCMs were characterized by using scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FT-IR), differential scanning calorimetry (DSC) and thermogravimetric (TG) analysis techniques. The SEM and FT-IR results proved the existence of good compatibility between the components of the composites due to capillary and surface tension forces. From the DSC analysis, the melting temperatures and the latent heat capacities of PEG600 (18 wt%)/gypsum and PEG600 (22 wt%)/natural clay composites were determined as $10.55 \pm 0.07^\circ\text{C}$, $24.18 \pm 1.0 \text{ J/g}$ and $10.85 \pm 0.05^\circ\text{C}$, $28.79 \pm 1.07 \text{ J/g}$, respectively. Thermal cycling test and TG analysis results exhibited that the prepared BCPCMs have good thermal reliability, chemical and thermal stability. In addition, the thermal performance test demonstrated that compared to the control cubicle, the inside centre temperatures of the cubicle made of PEG600/gypsum and PEG600/gypsum wallboards were recorded to be lower as averagely $2.08 \pm 0.02^\circ\text{C}$ for 60 min $1.47 \pm 0.01^\circ\text{C}$ for 120 min, respectively, during the heating periods.

15/00330 Corrosion susceptibility of EUROFER97 in lithium ceramics breeders

Hernández, T. *et al. Journal of Nuclear Materials*, 2014, 446, (1–3), 117–123.

EUROFER97 specimens were exposed in vacuum to lithium silicate pebbles at 550°C for up to 2880 h, to evaluate its corrosion susceptibility in a simulated breeder blanket environment. The specimens and pebble bed were then analysed and characterized by scanning electron microscopy with energy dispersive X-ray analysis, X-ray diffraction and high-resolution transmission electron microscopy (HR-TEM). The results revealed the formation of a double chromium/iron oxide corrosion layer. HR-TEM also showed that the inner layer was amorphous, while the outer was crystalline. The amorphous layer was brittle, broke easily, and became detached from the steel.

15/00331 Design of a flat glass furnace waste heat power generation system

Li, Z. *et al. Applied Thermal Engineering*, 2014, 63, (1), 290–296.

China is the largest glass producer in the world. Although the energy consumption of flat glass production has decreased significantly, from 12.6 MJ/kg in 2006 to 8.5 MJ/kg in 2010 and even lower now, very high energy recovery potential exists. A series of documents encouraging the development of glass furnace waste heat power generation systems have been issued by the Chinese government. There are already several waste heat power plants in China. This paper presents a power generation system using the waste heat from a 1200 t/d glass furnace. Two energy sources, namely natural gas and petroleum coke, are studied. The system steam output is 23 t/h, and the power output 5.2 MW. The high sulfur content in the petroleum coke requires large heating surface area of deaerator to prevent acid corrosion, leading to high investment cost and long payback period. The annual power supply is about 31 million kWh, which means that a saving of 12,400 tons of coal equivalent and a reduction of 0.84 MJ energy consumption of per kilogram of glass. The annual reduction of CO₂, SO₂, NO_x and dust are 28,500, 79, 83 and 33 tons, respectively.

15/00332 Development of a simplified method for intelligent glazed façade design under different control strategies and verified by building simulation tool BSIm

Liu, M. *et al. Building and Environment*, 2014, 74, 31–38.

The research aims to develop a simplified calculation method for intelligent glazed facade under different control conditions (night shutter, solar shading and natural ventilation) to simulate the energy performance and indoor environment of an office room installed with the intelligent facade. The method took the angle dependence of the solar characteristic into account, including the simplified hourly building model developed according to EN 13790 to evaluate the influence of the controlled facade on both the indoor environment (indoor air temperature, solar transmittance through the facade and the illuminance level on a chosen point) and the energy performance of the room. The parameters calculated by the simplified method were compared with the Danish building simulation tool BSIm in an hourly calculation with the weather data of the Danish reference year. By

12 REFRACTORIES/ CERAMICS

Properties, production, applications

15/00328 AC performance of silicone and glass barriers in clean and polluted atmosphere

Boudissa, R. *et al. Electric Power Systems Research*, 2014, 108, 170–177.

The aim of this article consists in the comparative study of silicone rubber and glass insulating barriers performance. The study is carried out under AC voltage in a clean and polluted atmosphere. Their dielectric properties needed to characterize their performance were measured using the Schering bridge. The effect of the grounded electrode's sizes and their isolation in the point-plane air gap system on the optimization of the insulating barrier performance was analysed. Moreover the authors present findings of experiments which allow quantifying the effects of the clean or polluted atmosphere, the degree of contamination, the number of polluted faces of the barrier as well as the electrode axis orientation of the rod-plane system on their protection reliability. Finally, this investigation has been supported by laboratory observations of the discharge phenomena in the air gap

using the simplified method, it is possible to calculate the whole year performance of a room or building with intelligent glazed façade, which makes it a less time consuming tool to investigate the performance of the intelligent façade under different control strategies in the design stage with acceptable accuracy. Results showed good agreement between the simplified method and BSIm in terms of simulating the energy and comfort performance of the room.

15/00333 Effects of water absorption and surface roughness on the bioreceptivity of ETICS compared to clay bricks

D'Orazio, M. *et al. Building and Environment*, 2014, 77, 20–28.
External thermal insulation composite systems (ETICS) have been used in European buildings since the 1970s due to the optimal protection from thermal loss, the low cost and the ease of application. The progressive thickening of ETICS used for either thermal insulation in new buildings or energy requalification of ancient buildings has facilitated the growth of microalgae on façades, due to limitation of outgoing heat flux, and hence to condensation of atmospheric moisture on building façade external layer. This study was aimed to comparatively evaluating the growth of two selected microalgal strains on ETICS and fired clay bricks; to this end, the influence of water absorption, porosity and surface roughness of these building materials was investigated. Biodeterioration of building materials was induced through a laboratory-accelerated growth test. Results from colorimetric and confocal laser scanning microscopy analyses clearly demonstrated that bioreceptivity of the building materials assayed is strongly affected by surface roughness and total porosity.

15/00334 Evaluation of electrochromic windows impact in the energy performance of buildings in Mediterranean climates

Tavares, P. F. *et al. Energy Policy*, 2014, 67, 68–81.
Old buildings refurbishment is essential for the global improvement of building energy indicators. Within this context, the paper focuses on the energy savings that may occur when using electrochromic (EC) windows, an interesting emerging technology alternative to shading devices to control solar gain in buildings located in Mediterranean climates. The EC windows technology is briefly presented and the optical properties adjustments of the glasses are discussed according to the operated range. The EC window dynamic behaviour and the different control strategies are modelled and implemented in the ESP-r building simulation program. The EC window impact in the energy needs for heating and cooling is studied, considering different ambient parameters (exterior dry bulb temperature, interior dry bulb temperature and incident radiation) and set points for the EC control. A comparison of several windows solutions (single, double-glazing and EC windows), the type of building, internal gains from occupancy, lighting and equipment and the orientation of windows are considered for discussion through the analysis of the energy needs for heating and cooling. It is concluded that for this climate the best positive results are obtained when the EC are used in the west façade. For the south façade the results show no significant advantages in using EC windows.

15/00335 Experimental characterisation and evaluation of the thermo-physical properties of expanded perlite – fumed silica composite for effective vacuum insulation panel (VIP) core

Alam, M. *et al. Energy and Buildings*, 2014, 69, 442–450.
The thermo-physical properties of expanded perlite-fumed silica composites were experimentally investigated as an alternative lower cost material for vacuum insulation panel (VIP) core using expanded perlite as a cheaper substitute of fumed silica. Pore size analysis was carried out using nitrogen sorption technique, mercury intrusion porosimetry and transmission electron microscopy and average pore size was estimated to be in the range of 50–150 nm. VIP core board samples measuring 100 mm × 100 mm and consisting of varying proportions of expanded perlite, fumed silica, silicon carbide and polyester fibre in the composite were prepared. The centre of panel thermal conductivity of the core board containing expanded perlite mass proportion of 60% was measured as 53 mW m⁻¹ K⁻¹ at atmospheric pressure and 28 mW m⁻¹ K⁻¹ when expanded perlite content was reduced to 30%. The centre of panel thermal conductivity with 30% expanded perlite content was measured as 7.6 mW m⁻¹ K⁻¹ at 0.5 mbar pressure. Radiative conductivity of the composite with expanded perlite mass of 30% was measured to be 0.3–1 mW m⁻¹ K⁻¹ at 300 K and gaseous thermal conductivity 0.016 mW m⁻¹ K⁻¹ at 1 mbar, a reduction of 8.3 mW m⁻¹ K⁻¹ from the value of gaseous thermal conductivity at 1 atm pressure. Opacifying properties of expanded perlite were quantified and are reported. A VIP core cost reduction potential of 20% was calculated through the use of expanded perlite in VIP core.

15/00336 Gamma radiation shielding and optical properties measurements of zinc bismuth borate glasses

Yasaka, P. *et al. Annals of Nuclear Energy*, 2014, 68, 4–9.
In this work, the zinc bismuth borate (ZBB) glasses of the composition 10ZnO : xBi₂O₃ : (90–x)B₂O₃ (where x = 15, 20, 25 and 30 mol%) were prepared by the melt quenching technique. Their radiation shielding and optical properties were investigated and compared with theoretical calculations. The mass attenuation coefficients of ZBB glasses have been measured at different energies obtained from a Compton scattering technique. The results show a decrease of the mass attenuation coefficient, effective atomic number and effective electron density values with increasing of γ -ray energies; and good agreements between experimental and theoretical values. The glass samples with Bi₂O₃ concentrations higher than 25 mol% (25 and 30 mol%) were observed with lower mean free path values than all the standard shielding concretes studied. These results are indications that the ZBB glasses in the present study may be developed as a lead-free radiation shielding material in the investigated energy range.

15/00337 Hollow glass microspheres for temperature and irradiance control in photobioreactors

Pereira, D. A. *et al. Bioresource Technology*, 2014, 158, 98–104.
The addition of hollow glass microspheres (HGM) to polymers to change thermal insulation and mechanical properties is widely used. In this study, HGM were tested as a new construction material for photobioreactors to control irradiance and broth temperature in microalgae cultivation. The heat isolation properties of HGMs of three different densities were tested in a polymer matrix. The transmittance (5–50%) and the thermal conductivity (182.05–190.73 W/mK) of the HGM composite material were analysed. The results were tested in a model to predict the broth temperature and the growth rate as a function of temperature and irradiance. The addition of 1.3 and 0.6 vol.% of HGM lead to an increase in the growth rate of up to 37% and a reduction in the broth temperature up to 9°C. The mechanical resistance of the composites tested is similar to the polymer matrix.

15/00338 Improving the thermal performance of red clay holed bricks

Costa, V. A. F. *Energy and Buildings*, 2014, 70, 352–364.
A numerical study is conducted to improve the thermal performance of red clay holed bricks, considering protuberances to inhibit natural convection and radiation heat transfer inside the brick holes. Protuberances are made of the same red clay and have the same thickness as the remaining elements of the bricks, the best solution leading to the lowest overall heat transfer rate with shorter protuberances. Protuberances increase conduction heat transfer but decrease natural convection and radiation heat transfer, and a minimum overall heat transfer exists. Protuberances allow an overall heat transfer reduction which increases as increases the Rayleigh number. For fixed solid material (red clay) and fluid (air), the Rayleigh number depends mainly on the temperature difference between the opposite faces of the brick. For increasing temperature differences, when the thermal performance of the buildings' walls is more important, protuberances increasingly improve the thermal performance of the bricks, giving to the bricks a smart character. Relevant information is obtained, helping holed bricks makers to obtain better bricks for energy savings and energy consumption reductions in buildings, the obtained results leading to overall heat transfer reductions up to 23%. Some comparisons are made with experimental results for common and commercially available red clay holed bricks without protuberances.

15/00339 Influence of superplasticizers on the long-term properties of cement pastes and possible impact on radionuclide uptake in a cement-based repository for radioactive waste

Wieland, E. *et al. Applied Geochemistry*, 2014, 49, 126–142.
Cementitious materials will be used for the construction of the engineered barrier of the planned repositories for radioactive waste in Switzerland. Superplasticizers (SPs) are commonly used to improve the workability of concretes and, along with a set accelerator (Acc), to produce shotcrete. In this study the influence of a polycarboxylate (PCE) and a polynaphthalene-sulfonate-based (PNS) SP on the hydration process, mineral composition and the sorption behaviour of metal cations has been investigated using an ordinary Portland cement (OPC), a low-alkali cement mix (LAC) consisting of CEM III-type cement and nanosilica, and a shotcrete-type cement mix (ESDRED) consisting of a CEM I-type cement and silica fume prepared in the presence of an alkali-free set accelerator. Both the PCE and PNS SP do not significantly influence the amount and quantity of hydrates formed during hydration. The concentration of both SPs decreased rapidly in the early stage of the hydration process for all cements due to sorption onto cement phases. After 28 days of hydration and longer, the concentration of the PNS SP in the pore

fluids of all cements was generally lower than that of the PCE SP, indicating stronger uptake of the PNS SP. The formate present in the Acc sorbs only weakly onto the cement phases, which led to higher aqueous concentration of organics in the ESDRED cement than in OPC and LAC. Sorption experiments with ^{63}Ni , ^{152}Eu and ^{228}Th on a cation exchange resin indicate that, at concentrations above 0.1 g L^{-1} , the two SPs could reduce sorption of metal cations. Thermodynamic modelling further indicates that radionuclide complexation by formate at the concentration level in Acc can be excluded, suggesting that the apparent effect of Acc in the sorption measurements on the resin can be attributed to colloids formed owing to the high concentrations of Al and S in Acc. Sorption studies with the same radionuclides on hardened cement paste (HCP) in the presence of concrete admixture solutions and pore fluids squeezed from cement pastes further revealed no significant effect on sorption by either the concrete admixtures or their degradation products that were potentially present in the pore fluids. This finding suggests that the investigated concrete admixtures (PNS, PCE, Acc) and their degradation products have no significant impact on radionuclide mobilization.

15/00340 Low temperature NH_3 -SCR over Zr and Ce pillared clay based catalysts

Boxiong, S. *et al. Fuel Processing Technology*, 2014, 119, 121–129.
A series of Zr and Ce pillared clay loaded with manganese oxide were prepared by wet-impregnation for the low temperature selective catalytic reduction (SCR) of NO . Various preparation methods for the $\text{MnO}_x/\text{Zr-Ce-PILC}$ catalysts were studied with respect to the effects on NO_x conversions. The $\text{MnO}_x(12\%)/\text{Zr-Ce-PILC}(30)$ catalyst prepared by the simultaneous Zr-Ce pillaring with a Zr:Ce molar ratio of 5:5 was demonstrated to be optimal in NH_3 -SCR reaction at low temperature, reaching 96% of NO_x conversion at 200°C . Various techniques were used to characterize these catalysts. N_2 physisorption results suggested that the simultaneous Zr-Ce pillaring enlarged the specific surface area and pore volume. The X-ray diffraction and X-ray photoelectron spectroscopy results illustrated that MnO_2 , Mn_2O_3 and Mn_3O_4 all existed on the surfaces of the catalysts. The results of H_2 -temperature programmed reduction NH_3 -temperature programmed desorption for the catalysts demonstrated that the $\text{MnO}_x(12\%)/\text{Zr-Ce-PILC}(30)$ catalyst had high redox characteristic and surface acidity. The shift of Mn and O elements to lower binding energies indicated more active for these elements in $\text{MnO}_x(12\%)/\text{Zr-Ce-PILC}(30)$. This demonstrated that Zr-Ce-PILC was a kind of potential support, which contributed to the high SCR activity of $\text{MnO}_x(12\%)/\text{Zr-Ce-PILC}(30)$.

15/00341 Method development for evaluating the redox state of Callovo-Oxfordian clayrock and synthetic montmorillonite for nuclear waste management

Didier, M. *et al. Applied Geochemistry*, 2014, 49, 184–191.
Understanding the redox characteristic of the host geological layer is vital for radioactive waste management. In order to predict the radionuclides behaviour during their release it must be thoroughly evaluated. This redox property could be affected by hydrogen gas which arises from the anaerobic corrosion of the stainless steel container. In this study, reduction methods using hydrogen gas or sodium dithionite as a reductive agent were tested on reference synthetic montmorillonites with various Fe(III) contents. The reduced samples were systematically studied with ^{57}Fe transmission Mössbauer spectrometry. After reduction with $\text{H}_2(\text{g})$ in dry conditions, the Mössbauer spectra are characterized by hyperfine parameters located between those for Fe(III) and Fe(II), compared to reduction in water suspension with $\text{Na}_2\text{S}_2\text{O}_4(\text{aq})$ and $\text{H}_2(\text{g})$ which gives standard Fe(II) hyperfine parameters. The former results with dry $\text{H}_2(\text{g})$ highlight an incomplete reduction and the possibility to have a Fe(III)-Fe(II) system with one-electron sharing. A natural clayrock sample, the Callovo-Oxfordian (COx), was also considered. The results above allowed its reduction to be evaluated. Much attention has also been focused on the modelling of the hyperfine spectra because of COx structure complexity. In addition, a hyperfine parameter data base was developed for a variety of Fe components based on an extensive literature review. This database provides additional statistical order to the study. This study highlights also that Mössbauer spectrometry remains a useful and non-destructive method to determine the reduction process and the reduction capacity of a reactant. Therefore the redox property of the rock can be estimated to evaluate and predict radionuclide behaviour for nuclear waste management.

15/00342 Modelling of Cs sorption in natural mixed-clays and the effects of ion competition

Missana, T. *et al. Applied Geochemistry*, 2014, 49, 95–102.
Cs migration in the environment is mainly controlled by sorption onto mineral surfaces, in particular on clay minerals. With the objective of designing a geochemical reactive barrier to treat ^{137}Cs accidental pollution in an industrial waste repository, different natural clayrocks were studied to analyse their capacity to retain Cs. The simple semi-empirical K_d -approach for experimental data analysis, is unsatisfactory to

describe the variability of sorption upon chemical changes. Indeed, due to the high salinity of the site, the effects of competitive ions must be evaluated and quantified. Thus, the development of sorption models, capable of reproducing experimental data obtained under conditions representative of the contaminated site, and applicable to reactive transport studies, is needed. In this study, a model for Cs sorption, which takes into account the main mineralogy of the sorbent, the composition of the natural water (and ion competition) was successfully applied to interpret the non-linear Cs sorption under natural conditions. The selectivity coefficients of Cs with respect to the most important cations present in the site water (Na , K , NH_4^+ , Ca) were derived by means of experiments in single clay minerals and synthetic mono-component solutions. Then, these parameters were tested in systems of increasing complexity. Considering the mineralogical composition of raw materials, it was shown that the principal contribution to Cs sorption is given by the mineral illite, while smectite starts to be relevant only at very high Cs loadings. Kaolinite, even in concentrations around 10wt% of the clayey fraction, played only a minor role. With respect to the solution composition, the model was able to predict Cs sorption in electrolyte concentrations up to twice than that of seawater and up to 500 mg/L NH_4^+ . The effect of highly competing ions, especially NH_4^+ and K^+ , on Cs retention is more important at low ionic strengths and low Cs loadings, where adsorption is dominated by illite selective frayed edge sites. Divalent cations are not especially relevant as competing cations for Cs.

15/00343 Performance analysis and comparison of two silicon material based photovoltaic technologies under actual climatic conditions in western India

Tripathi, B. *et al. Energy Conversion and Management*, 2014, 80, 97–102.
A study is conducted for solar photovoltaic (PV) energy generation from two grid-connected installations (mc-Si and a-Si power plants) located at the same place in Gujarat, western India. Data-sets on electricity production were collected over entire year and compared under actual climatic conditions. The final yield of mc-Si power plant varied from a lower value of 2.79 h/d in the month of August to a maximum value of 5.14 h/d in the month of March. Final yield for amorphous silicon power plant varied from a lower value of 2.62 h/d in the month of August to a maximum value of 4.84 h/d in the month of March. The performance ratio (PR) of the mc-Si power plant ranges from 57.1 to 93.14 and for a-Si power plant, PR ranges from 53.72 to 87.64. The a-Si solar PV power plant found to have high capture losses as compared to the mc-Si solar PV power plant.

15/00344 Photovoltaic effect in silicon treated by compression plasma flows

Uglov, V. V. *et al. Energy Procedia*, 2014, 44, 10–15.
Photovoltaic effect on single-crystalline silicon treated by compression plasma flows is studied. A number of samples ($1 \times 1\text{ cm}^2$) of single-crystalline silicon with n- and p-types of conductivity and different dopant concentrations (p-type silicon doped by B: 0.3, 4.5, 10, 12 $\Omega\text{ cm}$ n-type silicon doped by P: 0.5, 4.5, 20 $\Omega\text{ cm}$) were treated by nitrogen, hydrogen and helium compression plasma flows with energy density 5–12 J/cm^2 . Open-circuit voltage (AM1.5 spectrum of solar irradiation) dependence on plasma-forming gas, type of conductivity and dopant concentration was studied. It was established that photovoltaic effect takes place only in p-type silicon. The effect is maximal for boron concentration 4.5 $\Omega\text{ cm}$. Nitrogen plasma treatment causes appearance of photovoltaic effect for all types of p-silicon. At the same time after helium and hydrogen plasma treatment the effect is observable only for 4.5, 10 and 12 $\Omega\text{ cm}$ samples and is absent for 0.3 $\Omega\text{ cm}$ silicon. Thermoelectromotive force sign measurements show that the present effect is connected with appearance of new additional donors under plasma action in pre-surface layer. Possible reasons of donor appearance are silicon doping by nitrogen and appearance of thermo-donors. Compression plasma flows can be considered as perspective cheap method of silicon treatment for silicon based solar cell technology.

15/00345 Radiation effects on structural properties of glass by using ultrasonic techniques and FTIR spectroscopy: a comparison between local sand and SiO_2

Laopaiboon, R. and Bootjomchai, C. *Annals of Nuclear Energy*, 2014, 68, 220–227.
A comparison between local sand and SiO_2 with different compositions of CeO_2 with respect to the structural properties of glasses after successive irradiation was carried out by using ultrasonic techniques and Fourier transform infrared spectroscopy. The ultrasonic velocities were measured by the pulse echo technique, with a frequency of 4 MHz and at room temperature. From these obtained velocities and densities, various elastic moduli, micro-hardness and Poisson's ratio were calculated. The results indicate that local sand is more affected by gamma irradiation than SiO_2 . These results are due to a higher iron impurity in local sand leading to the occurrence more non-bridging oxygen.

15/00346 Solder transfer of carbon nanotube microfin coolers to ceramic chips

Mäklin, J. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 539–543. In this study, vertically aligned multi-walled carbon nanotubes are used as integrated microfin cooler structures on ceramic chips. The nanotube films are soldered on alumina test chips, which offer a fast, efficient and up-scalable transfer method. Metal coating on the tips of nanotubes is applied to improve solder wettability, adhesion, and to improve thermal interface between the cooler and the chip. The cooling performance of the carbon nanotubes based assemblies is comparable with their counterparts having copper-based coolers. The concept presented here shows the feasibility of carbon nanotubes integration into ceramic electrical components and packages with the potential of large-scale production.

15/00347 Thin-film silicon solar cells on dry etched textured glass

Zhang, W. *et al. Energy Procedia*, 2014, 44, 151–159. This study reports on the development of thin-film silicon solar cells on textured glass substrates. The textured glass substrates are fabricated by ion beam etching using a wet-chemically textured three-dimensional etching mask. The development of transparent and conductive front contact ZnO:Al films on textured glass is presented. The optimum of the front contact layer thickness was found to be 60 nm. For this thickness deteriorating reflection maxima are avoided, which occur due to the interferences in the front contact layer. The glass texture is adjusted to achieve better light trapping in the near infrared range. In addition, ITO instead of ZnO:Al film was investigated to surpass the decreased fill factor of solar cells deposited on ZnO:Al thin front contacts.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

15/00348 Advantages and limitations of exergy indicators to assess sustainability of bioenergy and biobased materials

Maes, D. and Van Passel, S. *Environmental Impact Assessment Review*, 2014, 45, 19–29. Innovative bioenergy projects show a growing diversity in biomass pathways, transformation technologies and end-products, leading to complex new processes. Existing energy-based indicators are not designed to include multiple impacts and are too constrained to assess the sustainability of these processes. Alternatively, indicators based on exergy, a measure of 'qualitative energy', could allow a more holistic view. Exergy is increasingly applied in analyses of both technical and biological processes. But sustainability assessments including exergy calculations, are not very common and are not generally applicable to all types of impact. Hence it is important to frame the use of exergy for inclusion in a sustainability assessment. This paper reviews the potentials and the limitations of exergy calculations, and presents solutions for coherent aggregation with other metrics. The resulting approach is illustrated in a case study. Within the context of sustainability assessment of bioenergy, exergy is a suitable metric for the impacts that require an ecocentric interpretation, and it allows aggregation on a physical basis. The use of exergy is limited to a measurement of material and energy exchanges with the sun, biosphere and lithosphere. Exchanges involving services or human choices are to be measured in different metrics. This combination provides a more inclusive and objective sustainability assessment, especially compared to standard energy- or carbon-based indicators. Future applications of this approach in different situations are required to clarify the potential of exergy-based indicators in a sustainability context.

15/00349 Cold season ammonia emissions from land spreading with anaerobic digestates from biogas production

Köster, J. R. *et al. Atmospheric Environment*, 2014, 84, 35–38. Anaerobic digestates (AD) from biogas production are applied to agricultural land as organic fertilizers, but pose an ammonia (NH₃) emission source. However, data about NH₃ emissions of cold season AD land spreading is still lacking. Therefore, in the present study NH₃ emissions of AD application under winter conditions were determined. AD was applied via trail hoses to a field plot of 27 ha in northern Germany during the winter with temperatures around the freezing point and partly frozen soil. NH₄⁺ N application rate was, including a

preceding urea application, 123 kg NH₄⁺ and urea N ha⁻¹. The NH₃ volatilization was monitored using open path Fourier transform infrared spectroscopy in combination with a micrometeorological transport model. Cumulative NH₃ volatilization during the 6-day measurements was 17.5 kg NH₃ N ha⁻¹ which corresponds to 33.1% of the NH₄⁺ N in applied AD. This NH₃ loss is relatively high for low temperature conditions and was most likely caused by the frozen soil restricting AD infiltration.

15/00350 Enzymatic biodiesel production of microalgae lipids under supercritical carbon dioxide: process optimization and integration

Taher, H. *et al. Biochemical Engineering Journal*, 2014, 90, 103–113. Enzymatic biodiesel production in supercritical CO₂ (SC-CO₂) has recently received an increasing attention, as an alternative to the conventional chemical processes. In this study, enzymatic production of biodiesel from microalgal lipids was investigated in batch and integrated extraction-reaction systems. In the batch system, the effect of enzyme loading (15–50 wt%), temperature (35–55 °C) and methanol to lipid molar ratios (3–15:1) were studied, and response surface methodology was employed to optimize selected factors effect. The optimum transesterification yield of 80% was obtained at 47 °C, 200 bar, 35% enzyme loading, and 9:1 molar ratio after 4 h reaction in the batch system. The experimental results were also used to determine the kinetics parameters of the Ping-Pong Bi Bi model, with methanol inhibition, suggested to describe the reaction. In the continuous integrated extraction-reaction system, the effect of methanol to lipids molar ratio was investigated, and enzyme operational stability and reusability were tested. Bed regeneration by *tert*-butanol washing was also assessed. The optimum methanol to lipid ratio was found to be 10:1. At this ratio, the enzyme was able to attain 78% of its original activity when reused for six continuous cycles, and the bed was successfully reused by washing with *tert*-butanol.

15/00351 Fuel properties and rheological behavior of biodiesel from egusi (*Colocynthis citrullus* L.) seed kernel oil

Giwa, S. O. *et al. Fuel Processing Technology*, 2014, 122, 42–48. In this study, egusi (*Colocynthis citrullus* L.) seed kernel oil has been evaluated as a feedstock for biodiesel production. The transesterification of the crude egusi seed kernel oil (CESKO) via methanol in the presence of sodium methoxide was performed and the resulting egusi oil methyl ester (EOME) was tested for its fatty ester composition, fuel properties and rheological behaviour (at 25, 40 and 55 °C). The fuel properties of EOME measured met both the ASTM D6751 and EN 14214 biodiesel standards, with the exception of lower oxidative stability. The fatty ester composition and fuel properties of EOME were found comparable to those of conventional biodiesels from soybean, sunflower and safflower oils. The viscosity behaviour of EOME and its blends with diesel fuel (at 25, 40 and 55 °C) was found to be pseudoplastic and Newtonian in nature and this agrees with those of other biodiesels reported in literature. From this study, the kinematic viscosity of EOME (3.91 mm²/s) was found to be slightly lower than that of most biodiesels (≥ 4.0 mm²/s) reported in literature.

15/00352 Heterogeneous CaO–MoO₃–SBA-15 catalysts for biodiesel production from soybean oil

Xie, W. and Zhao, L. *Energy Conversion and Management*, 2014, 79, 34–42.

The main aim of this research is to develop efficient and environmentally benign heterogeneous catalysts for biodiesel production. For this purpose, heterogeneous CaO–MoO₃–SBA-15 catalysts were prepared by incipient impregnation method, and the prepared catalyst was tested for the transesterification process of soybean oil to produce biodiesel. Various techniques such as X-ray diffraction, Fourier transform infrared spectra, X-ray photoelectron spectroscopy, scanning electron microscopy and thermo gravimetric analysis were employed for the characterization of the solid catalyst. The catalytic activity was dependent on the calcination temperature and loading amount of calcium and molybdenum oxides. The solid catalyst, with the CaO–MoO₃ loading of 40% and calcined at 823 K, showed the best catalytic activity. The effect of methanol/oil molar ratio, reaction time, catalyst loading and catalyst stability was investigated. By using a 6 wt% of catalyst with methanol/oil molar ratio of 50:1 at reflux of methanol, the oil conversion of 83.2% after 50 h of reaction, could be achieved over the solid catalyst. The catalyst can be easily recovered and reused without significant loss of activity.

15/00353 Hydrothermal liquefaction of *Chlorella pyrenoidosa* for bio-oil production over Ce/HZSM-5

Xu, Y. *et al. Bioresource Technology*, 2014, 156, 1–5. This paper investigated a novel hydrothermal liquefaction process of *Chlorella pyrenoidosa* catalysed by Ce/HZSM-5. The chemical groups and components of the residues of *C. pyrenoidosa* were analysed by Fourier transform infrared spectrometry and gas chromatography–

mass spectrometry. The crystal structure and microsurface topography of *C. pyrenoidosa* before and after catalytic liquefaction were characterized by X-ray diffraction and scanning electron microscopy, respectively. The experimental results showed that the catalytic cracking effects of Ce/HZSM-5 were superior to that of HZSM-5 as a liquefaction catalyst of *C. pyrenoidosa*. Compared with HZSM-5, Ce/HZSM-5 has a significantly enhanced Lewis acid active centre, smaller particle size, larger specific surface, and highly dispersed Ce₄O₇ with trivalent and tetravalent cerium in the zeolite skeleton channel that accelerate the catalytic liquefaction of *C. pyrenoidosa*. The rare earth modified zeolite Ce/HZSM-5 exhibits good potential and a beneficial nature for the preparation of bio-oil from microalgae with high efficiency.

15/00354 Microbial biodiesel production by direct methanolysis of oleaginous biomass

Thliveros, P. *et al. Bioresource Technology*, 2014, 157, 181–187.

Biodiesel is usually produced by the transesterification of vegetable oils and animal fats with methanol, catalysed by strong acids or bases. This study introduces a novel biodiesel production method that features direct base-catalysed methanolysis of the cellular biomass of oleaginous yeast *Rhodospiridium toruloides* Y4. NaOH was used as catalyst for transesterification reactions and the variables affecting the esterification level including catalyst concentration, reaction temperature, reaction time, solvent loading (methanol) and moisture content were investigated using the oleaginous yeast biomass. The most suitable pretreatment condition was found to be 4 g L⁻¹ NaOH and 1:20 (w/v) dried biomass to methanol ratio for 10 h at 50 °C and under ambient pressure. Under these conditions, the fatty acid methyl ester (FAME) yield was 97.7%. Therefore, the novel method of direct base-catalysed methanolysis of *R. toruloides* is a much simpler, less tedious and time-consuming, process than the conventional processes with higher FAME (biodiesel) conversion yield.

15/00355 Operation of a bioelectrochemical system as a polishing stage for the effluent from a two-stage biohydrogen and biomethane production process

Fradler, K. R. *et al. Biochemical Engineering Journal*, 2014, 85, 125–131.

Anaerobic bioenergy production processes including fermentative biohydrogen (BioH₂), anaerobic digestion (AD) and bioelectrochemical system have been investigated for converting municipal waste or various biomass feedstock to useful energy carriers. However, the performance of a microbial fuel cell (MFC) fed on the effluent from a two-stage biogas production process has not yet been investigated extensively in continuous reactor operation on complex substrates. This study investigated the extent to which a microbial fuel cell (MFC) can reduce chemical oxygen demand (COD) and recover further energy from the effluent of a two-stage biohydrogen and biomethane system. The performance of a four-module tubular MFC was determined at six different organic loadings (0.036–6.149 g sCOD L⁻¹ d⁻¹) in terms of power generation, COD removal efficiency, coulombic efficiency (CE) and energy conversion efficiency (ECE). A power density of 3.1 W m⁻³ was observed at the OLR = 0.572 g sCOD L⁻¹ d⁻¹, which resulted in the highest CE (60%) and ECE (0.8%), but the COD removal efficiency decreased at higher organic loading rates (35.1–4.4%). The energy recovery was 92.95 J L⁻¹ and the energy conversion efficiency, based on total influent COD was found to be 0.48–0.81% at 0.572 g sCOD L⁻¹ d⁻¹. However, the energy recovery by the MFC is only reported for a four-module reactor and improved performance can be expected with an extended module count, as chemical energy remained available for further electrogenesis.

15/00356 Optimization of biodiesel production from soybean oil in a microreactor

Rahimi, M. *et al. Energy Conversion and Management*, 2014, 79, 599–605.

Transesterification of soybean oil with methanol in the presence of potassium hydroxide, as a catalyst, in a microreactor has been investigated. The transesterification reaction was performed at specific condition in circular tubes with hydraulic diameter of (0.8 mm). In order to further improve the biodiesel production, the experimental design was performed using Box–Behnken method. The results were analysed using response surface methodology. The influence of reaction variables including: molar ratio of methanol to oil (6:1–12:1), temperature (55–65 °C) and catalyst concentration (0.6–1.8 wt%) and residence time (20–180 s) under various flow rates of reactants (1–11 ml min⁻¹) on fatty acid methyl ester (FAME) transesterification reaction was studied. The optimum condition was found at molar ratio of methanol to oil (9:1), catalyst concentration (1.2 wt%) and temperature (60 °C) with a FAME % of about 89%. Considering optimum parameters, by changing the reactant residence time the FAME % was reached to 98% at 180 s.

15/00357 Probabilistic optimal allocation of biomass fueled gas engine in unbalanced radial systems with metaheuristic techniques

Gomez-Gonzalez, M. *et al. Electric Power Systems Research*, 2014, 108, 35–42.

This paper shows that in order to solve a probabilistic three-phase load flow in radial distribution networks, it is necessary to apply effective techniques that take into account their technical constraints. Among these constraints, voltage regulation is one of the principal problems to be addressed in distributed generation. To evaluate the performance of this distribution system, this paper has developed a probabilistic model that takes into account the random nature of lower heat value of biomass and load. This paper applies a new method utilizing shuffled frog-leaping algorithm and three phase probabilistic load flow combined with the Monte Carlo method to solve this problem. The proposed method determines the nodes where biomass-fuelled gas engines are connected and their mean power output in order to minimize the voltage unbalances at the nodes. Acceptable solutions are reached in a small number of iterations. Results prove that the proposed method can be applied for the keeping of voltages within desired limits at all load buses of a distribution system with biomass-fuelled gas engines. Numerical applications are presented and considered regarding the unbalanced distribution system IEEE 13-nodes. The results obtained show the decrease of the unbalance factor due to the presence of distributed generation.

15/00358 Sodium zirconate (Na₂ZrO₃) as a catalyst in a soybean oil transesterification reaction for biodiesel production

Santiago-Torres, N. *et al. Fuel Processing Technology*, 2014, 120, 34–39.

Sodium zirconate (Na₂ZrO₃) was tested as a basic catalyst for the production of biodiesel using a soybean oil transesterification reaction. Initially, Na₂ZrO₃ was synthesized via a solid-state reaction. The structure and microstructure of the catalyst were characterized using X-ray diffraction, scanning electron microscopy and N₂ adsorption. Various transesterification reactions were then conducted using soybean oil and methanol under differing reaction conditions. The influence of some parameters, such as the reactant concentrations (molar ratios), catalyst percentage, reaction time, temperature and re-use of the catalyst, on the transesterification process in the presence of Na₂ZrO₃ was investigated. The maximum FAME conversion efficiency was 98.3% at 3 h of reaction time and 3% of catalyst. Additionally, the produced biodiesel was characterized using infrared spectroscopy, gas chromatography coupled to mass spectrometry and proton nuclear magnetic resonance. The resulting biodiesel showed good purity, composition and degree of unsaturation in comparison to previous reports. According to these results, Na₂ZrO₃ could become an alternative solid base catalyst for scalable and cost-effective biodiesel production.

15/00359 Techno-economic analysis of biooil production process from palm empty fruit bunches

Do, T. X. *et al. Energy Conversion and Management*, 2014, 80, 525–5340.

Empty fruit bunches (EFB), a main residue of the palm oil industry, are one of the most recent renewable energy resources and they promise a high yield of liquid with low gas and char. The objective of this study is to evaluate the economic feasibility of the biooil production process from EFB via fast pyrolysis using a fluidized bed. A comprehensive model of a biooil production plant was developed utilizing a commercial process simulator. The total capital investment was estimated for five different plant sizes. The EFB biooil plant was analysed in terms of the specific capital cost, payback period, return on investment, and the product value. The minimum profitable plant size was found to be 20 kton-dry EFB/yr at a product value of \$0.47/kg of biooil including 39% of water. Sensitivity analysis was performed on the basis of the minimum plant size to identify key variables that have a strong impact on the product value. The plant size and the biooil yield showed a major influence on the product value. In the most optimistic scenario investigated in this study, biooil can be produced at a product value of \$0.27/kg.

15/00360 The Colombian biofuel supply chains: the assessment of current and promising scenarios based on environmental goals

Valencia, M. J. and Cardona, C. A. *Energy Policy*, 2014, 67, 232–242.

Colombian biofuels are used in the transportation sector at low-percentage blends of biofuel–fossil fuel (8:92 volume basis). Since energy policies encourage the percentage of bioenergy in the energy matrix, biofuels production and use should be increased during the coming years. In this work, an environmental assessment of several scenarios involving current and promising biofuel supply chains was made. The aim of this paper was the assessment of several possible alternatives to increase the biofuels production from current agricultural supply chains. Sugarcane, cassava, oil-palm and jatropha were

considered as feedstocks for the analysis. The environmental assessment included calculations of the greenhouse gas emissions and the potential environmental impacts, using the life cycle assessment approach. The results indicated that current biofuels production mitigates environmental impacts in comparison to fossil fuels production and use. Additionally, biofuels production using promising feedstocks could be environmentally competitive if the production processes are improved.

15/00361 The effect of biodiesel policies on world biodiesel and oilseed prices

Drabik, D. *et al. Energy Economics*, 2014, 44, 80–88.

A theoretical and empirical model is developed to analyse the effect of a biodiesel mandate, a tax exemption (tax credit) and an exogenous diesel price shock on world soybean and canola markets. The jointness in crushing oil and meal from the oilseed reduces the size of the link between biodiesel and oilseed prices. A diesel price shock with a mandate results in a smaller change in oilseed prices compared with a tax exemption. Higher diesel prices increase biodiesel prices under a tax exemption but lower them with a blend mandate. When both canola and soybeans are used to produce biodiesel, an increase in the diesel price leads to higher canola prices, but the effect on soybean prices is ambiguous and depends on relative elasticities of meal demand and canola supply because canola produces more oil than soybeans.

15/00362 The headspace of microaerobic reactors: sulphide-oxidising population and the impact of cleaning on the efficiency of biogas desulphurisation

Ramos, I. *et al. Bioresource Technology*, 2014, 158, 63–73.

Oxygen-limiting/microaerobic conditions were applied in order to control the H_2S content of biogas. The S^0 -rich deposits found all over the headspace of two pilot reactors (R1 and R2) as a result of operating under such conditions for 7 and 15 months, respectively, were sampled and removed. After restarting micro-oxygenation, H_2S -free biogas was rapidly obtained, and the O_2 demand of R2 decreased. This highlighted the need for a cleaning interval of less than 14 months in order to minimize the micro-oxygenation cost. The H_2S removed from R2 after approximately 1 month was recovered from its headspace as S^0 , thus indicating that the biogas desulfurization did not take place at the liquid interface. Denaturing gradient gel electrophoresis indicated that the composition, species richness and size of the sulfide-oxidizing bacteria population depended on the location, and, more specifically, moisture availability, and indicated increasing species richness over time. Additionally, a possible succession was estimated.

15/00363 The impact of biomass quality and quantity on the performance and economics of co-firing plants with and without CO_2 capture

Khorshidi, Z. *et al. International Journal of Greenhouse Gas Control*, 2014, 21, 191–202.

Co-firing biomass with coal has been proposed as a near term option for CO_2 mitigation because it can be retrofitted to coal plants without major modifications. If CO_2 capture is also implemented, negative emissions may result. Such negative emissions provide additional CO_2 credits that can reduce the overall cost of capture. This paper investigates the impact of biomass quality and quantity on the performance and economics of co-firing plants with and without capture. Three biomass feedstocks (wood chips, conventional wood pellets and torrefied wood pellets) were considered at three co-firing levels (5%, 20% and 40%). The results show that increasing biomass quality improves plant performance with a moderate increase in cost of electricity. At the highest co-firing level the plant emission intensity would be about $0.5 \text{ t } CO_2/\text{MWh}$ without capture and $-0.5 \text{ t } CO_2/\text{MWh}$ with capture while the change in cost of electricity is relatively small at no more than 9.5%. General correlations for cost of electricity are developed that quantify the impact of fuel prices, carbon price and renewable energy certificates on cost of electricity as a function of biomass quality and quantity. At present, co-firing requires relatively modest incentives while the addition of capture requires higher incentives.

15/00364 Thermodynamic modeling of iron and trace metal solubility and speciation under sulfidic and ferruginous conditions in full scale continuous stirred tank biogas reactors

Yekta, S. S. *et al. Applied Geochemistry*, 2014, 47, 61–73.

This study investigated the equilibrium chemistry and chemical speciation of S, Fe and metals (Co, Ni, Cu, Zn, Cd and Pb) in eight full-scale continuous stirred tank biogas reactors (CSTBR). Five reactors were digesting mixtures of different organic wastes (referred to as co-digester; CD) and three were digesting sewage sludge (SS). Iron was continuously added to the CD reactors to remove sulfide produced during anaerobic digestion and SS was rich in Fe, amended for phosphate removal in wastewater treatment plants prior to anaerobic digestion. As a consequence of different S:Fe molar ratios

(0.3–2.8), ferruginous (Fe(II)-dominated) conditions prevailed in SS reactors and sulfidic (S(-II)-dominated) conditions in CD reactors. In all reactors, the chemical speciation of S, as determined by S K-edge X-ray absorption near-edge structure spectroscopy, was dominated by $FeS(s)$. Reduced organic S forms, consisting of RSH (thiol) and RSR (organic sulfide), were the second most abundant S species. Zero-valent S (elemental S, polysulfides, and possible traces of pyrite) was detected in all reactors, ranging between 6% and 26% of total S, with the highest proportion formed under ferruginous conditions. Thermodynamic modelling suggested that Fe in the aqueous phase was dominated by Fe(II)-thiol complexes under sulfidic conditions (CD reactors) and by Fe(II)-phosphate complexes under ferruginous conditions (SS reactors). Thiols, representing organic functional groups, and sulfide complexes were the major aqueous species of Co(II), Ni(II), Cd(II) and Pb(II) under sulfidic conditions. Under ferruginous conditions thiol complexes were still important, but carbonate and phosphate complexes in particular dominated the aqueous phase speciation of Co(II) and Ni(II). The aqueous phase speciation of Zn and Cu was dominated by Zn(II)-sulfide and Cu(I)-polysulfide complexes, respectively. The results highlight the importance of S:Fe molar ratio as a regulating factor for the chemical speciation of metals in biogas reactors which in turn is important for microbial trace metal uptake and growth as well as potential metal toxicity. Both these aspects are critical for a successful performance of biogas production process.

15/00365 Two-stage thermal conversion of inedible lipid feedstocks to renewable chemicals and fuels

Asomaning, J. *et al. Bioresource Technology*, 2014, 158, 55–62.

The aim of this work was to study the conversion of inedible, low-cost lipid feedstocks to renewable hydrocarbons using a two-stage thermal hydrolysis-pyrolysis method. Beef tallow, yellow grease, brown grease and cold pressed camelina oil were first hydrolysed and the fatty acids produced were recovered and pyrolysed in batch reactors. The pyrolysis products were identified and quantified using gas chromatography and mass spectrometry. The pyrolysis product yields were similar for all the feedstock used with the organic liquid fraction (OLF) accounting for 76–80% of the product. The OLF consisted predominantly of *n*-alkanes. Approximately 30% OLF constituted a gasoline-equivalent fraction and 50% a diesel fraction. Other fuel property test showed that the OLF met the specifications set out by the Canadian general standards board. This research demonstrated a novel two-stage thermal hydrolysis-pyrolysis conversion method for producing OLF from inedible and low-value lipids.

15/00366 Ultrasound-enhanced rapid in situ transesterification of marine macroalgae *Enteromorpha compressa* for biodiesel production

Suganya, T. *et al. Bioresource Technology*, 2014, 156, 283–290.

In situ transesterification of *Enteromorpha compressa* algal biomass was carried out for the production of biodiesel. The maximum methyl esters (ME) yield of 98.89% was obtained using ultrasonic irradiation. Tetrahydrofuran (THF)-acid catalyst (H_2SO_4) was found to be an appropriate co-solvent and catalyst for high free fatty acids (FFA) content *E. compressa* biomass to increase the efficiency of the reactive *in situ* process. The optimization study was conducted to obtain the maximum yield and it was determined as 30 vol% of THF as a co-solvent, 10 wt% of H_2SO_4 , 5.5:1 ratio of methanol to algal biomass and 600 rpm of mixing intensity at $65^\circ C$ for 90 min of ultrasonic irradiation time. The produced biodiesel was characterized by ^1H nuclear magnetic resonance spectroscopy analysis. Kinetic studies revealed that the reaction followed the first-order reaction mechanism. Rapid *in situ* transesterification was found to be suitable technique to produce biodiesel from marine macroalgae feedstock.

Geothermal energy

15/00367 A model for a borehole heat exchanger working with CO_2

Mastrullo, R. *et al. Energy Procedia*, 2014, 45, 635–644.

Ground-source heat pumps are a valid technology for heating and cooling in residential application, since they allow one to have a stable temperature of the heat source/sink by means of ground heat exchangers, generally named as boreholes. In particular, U-pipe heat exchangers are interesting when working with two-phase fluids, especially during the heating season, when natural circulation might occur. This work presents the model of a borehole heat exchanger working with carbon dioxide as secondary fluid in a U-pipe loop. A closed system of equations is introduced with appropriate correlations for heat transfer and pressure drops, accounting for transient heat conduction due to ground temperature variation. Maps of performance

varying the main operating parameters are presented and discussed, showing the potential of the model as tool for sensitivity analysis and as sub-model to find the matching between the heat pump and the borehole heat exchanger.

15/00368 A new solution for underground thermal imbalance of ground-coupled heat pump systems in cold regions: heat compensation unit with thermosyphon

You, T. *et al. Applied Thermal Engineering*, 2014, 64, (1–2), 283–292. Ground-coupled heat pump systems (GCHPs) are environmentally friendly and energy-saving heating and cooling sources that are widely applied in recent years. However, for heating-dominant buildings in cold regions, more heat is extracted from the ground than is rejected, which leads to yearly decrease in soil temperature and degradation of the GCHP's heating performance and even results in GCHP failure after long-term operation. To solve this problem, a novel heat compensation unit with thermosyphon (HCUT) is proposed. The HCUT combines an air-source thermosyphon and an air-source heat pump to transfer heat from ambient air into the ground during the non-heating season as seasonal thermal storage and to recover the soil temperature. To investigate its long-term operation performance, a multi-year simulation was conducted in Harbin (one of the coldest cities in China) by TRNSYS, and the performance of the novel system is compared with the traditional 'boiler + split air-conditioner' system. The results indicate that HCUT can effectively eliminate the underground thermal imbalance in cold regions, while ensuring that the GCHP system continues to work efficiently without performance deterioration and strengthening the heating reliability. Additionally, the novel system can save approximately 15% in energy compared with the traditional system. Thus, the HCUT is a potential solution for the underground thermal imbalance of GCHP systems in cold regions.

15/00369 An experimental investigation on the combined use of phase change material and rock particles for high temperature (~350 °C) heat storage

Okello, D. *et al. Energy Conversion and Management*, 2014, 79, 1–8. The intermittent nature of solar energy requires integration of an energy storage system with solar collector devices in order to have uninterrupted supply of energy in the absence of the availability of solar energy. The use of phase change material (PCM) and rock bed for heat storage has been studied in the past decades. However, limited knowledge exists on the use of the combination of PCM and rock particles for high temperature heat storage with air as the medium of heat transfer. The aim of this paper is to show experimentally by means of comparison, the thermal behaviours of thermal energy storage with only rocks and that with rocks and PCM. A heat storage consisting of only rocks and that with rocks and PCM has been designed and built. The PCM material used is a mixture of NaNO₃ and KNO₃ in the ratio of 60:40% (mol%). The charging and thermal de-stratification profiles were investigated for both cases. The results showed that the introduction of PCM cylinders in a bed of rocks for heat storage does not only increase the energy content of the storage but it also increases the vertical thermal conductivity. The increase in vertical thermal conductivity is attributed to the high thermal conductivity of the PCM container material.

15/00370 Binary ORC (organic Rankine cycles) power plants for the exploitation of medium–low temperature geothermal sources – part A: thermodynamic optimization

Astolfi, M. *et al. Energy*, 2014, 66, 423–434. This paper investigates the potential of organic Rankine cycles (ORC) for the exploitation of low-medium enthalpy geothermal brines. Part A deals with thermodynamic analysis and optimization, while part B focuses on economic optimization. In the ORC field, the wide range of available working fluids and cycle configurations entail a non-univocal selection of fluid and cycle parameters for the exploitation of a given heat source. A Matlab code was created in order to define the optimal combination of fluid, cycle configuration and cycle parameters. Thermodynamic properties of fluids are taken from the Refprop database. An extensive thermodynamic analysis is performed considering geothermal sources in the temperature range of 120–180 °C. All the assumptions for calculating the plant components' performance are set on the basis of data from literature and real power plants data sheets. Thermodynamic optimization results, shown in terms of reduced variables, allow defining some general rules for the selection of the optimal combination of working fluid and cycle configuration. In particular, it is found that configurations based on supercritical cycles, employing fluids with a critical temperature slightly lower than the temperature of the geothermal source, lead to the highest efficiencies for most of the investigated cases.

15/00371 Binary ORC (organic Rankine cycles) power plants for the exploitation of medium–low temperature geothermal sources – part B: techno-economic optimization

Astolfi, M. *et al. Energy*, 2014, 66, 435–446.

This investigates the potential of organic Rankine cycles (ORC) for the exploitation of low-medium enthalpy geothermal brines. Part A deals with thermodynamic analysis and optimization, while part B focuses on economic optimization. In this part, an economic model was defined and implemented in the Matlab code developed previously. A routine was also implemented to estimate the design of the turbine (number of stages, rotational speed, mean diameter), allowing one to estimate the turbine efficiency and cost. The developed tool allowed an extensive techno-economic analysis to be performed of the many cycles exploiting geothermal brines with temperatures between 120 and 180 °C. By means of an optimization routine, the cycles and the fluids leading to the minimum cost of the electricity are found for each geothermal source considered. Cycle parameters found from the techno-economic optimization are compared with those assumed and found from the thermodynamic optimization. Quite relevant differences show the necessity to perform optimization on the basis of specific plant cost. As a general trend, it is however confirmed that configurations based on supercritical cycles, employing fluids with a critical temperature slightly lower than the temperature of the geothermal source, lead to the lowest electricity cost for most of the investigated cases.

15/00372 Characteristics of ground thermal properties in Harbin, China

Zhang, Y. *et al. Energy and Buildings*, 2014, 69, 251–259.

Eleven representative sites were selected in this study to present the characteristics of ground thermal properties in Harbin, China. The initial ground temperature field was measured, and the temperature ranges of the solar warming, constant temperature, and increasing temperature layers were determined. The 22 thermal response tests (TRTs) for 11 boreholes were examined with two heating powers (4.2 and 6.5 kW). The analysis of thermal properties was performed in the laboratory. A total of 337 representative samples of rock and soil were analysed, and their thermal properties were measured in laboratory tests, and the results of these tests are not consistent with those of TRTs. The overall characteristics of ground thermal conductivity were determined according to overall distribution. In this study, the data obtained clearly indicate that there is a potential for the efficient use of ground source heat pumps (GSHPs) in Harbin. In the future, a demonstrating project will be constructed to estimate performance and economic feasibility of the GSHP systems according to the study results.

15/00373 Conventional and advanced exergoeconomic analyses of geothermal district heating systems

Keçebaş, A. and Hepbasli, A. *Energy and Buildings*, 2014, 69, 434–441. The present study deals with analysing, assessing and comparing conventional and advanced exergoeconomic analyses to identify the direction and potential for energy savings of a geothermal district heating system in future conditions/projections. As a real case study, the Afyon geothermal district heating system in Afyonkarahisar, Turkey, is considered while its actual operational thermal data on 8 February 2011 are used in the analysis, which is based on the specific exergy costing method. In this study for the first time, based on the concepts of avoidable/unavoidable and endogenous/exogenous parts, cost rates associated with both exergy destruction and capital investment of the geothermal district heating system are determined first, and the obtained results are then evaluated. The results indicate that the internal design changes play a more essential role in determining the cost of each component. The cost rate of unavoidable part within the components of the system is lower than that of the avoidable one. For the overall system, the value for the conventional exergoeconomic factor is determined to be 5.53% while that for the modified one is calculated to be 9.49%. As a result, the advanced exergoeconomic analysis makes more sense given the additional information in splitting process of the components.

15/00374 Effects of different operating conditions of Gonen geothermal district heating system on its annual performance

Aslan, A. *et al. Energy Conversion and Management*, 2014, 79, 554–567. In this paper, the effects of different operating conditions of the Gonen, Turkey, geothermal district heating system (GDHS) on its annual energy and exergy performance are investigated. The system parameters such as temperature, pressure and flow rate are monitored by using fixed and portable measuring instruments over a 1-year period. Thus the main differences in the annual system operation are detected. The measurements show that the Gonen GDHS has six different operating cases depending on the outside temperature throughout the year. The energy and exergy analysis of the system is carried out for each case using the actual system parameters at the corresponding reference temperatures, which are 3.86, 7.1, 8.88, 11.83, 15.26 and 20.4 °C. The highest and lowest energy (57.32%, 35.64%) and exergy (55.76%, 41.42%) efficiencies of the overall system are calculated at the reference temperatures of 15.26 and 3.86 °C,

respectively. Besides, taking the six case-based energy and exergy analyses into account, the annual average energy and exergy efficiencies are determined to be 45.24% and 47.33%, respectively.

15/00375 Enhanced geothermal systems in Europe: an estimation and comparison of the technical and sustainable potentials

Chamorro, C. R. *et al. Energy*, 2014, 65, 250–263.

This study presents an estimation and comparison of the technical and sustainable potentials of enhanced geothermal systems (EGS) in Europe. The temperatures at depths of 3500–9500 m were first calculated from the available data of temperatures at surface, 1000 and 2000 m depth, and heat flow. Next, the available thermal energy stored in each 1000-m thick layer along the considered depths was evaluated. At this point, the EGS technical potential was estimated and results are presented as installable net electrical power by considering a 30-year time project. A method to estimate the EGS sustainable potential is proposed and the results are compared with the technical potential. Results are presented for the European territory as a whole and individually for each one of the European countries. Estimations for Turkey and the Caucasus region are also provided. Under the hypotheses considered in this study, the technical potential of EGS in Europe for temperatures above 150 °C and depths of between 3 and 10 km was estimated to be more than 6500 GW_e. The part of this technical potential that can be considered as 'sustainable' or 'renewable' potential was estimated to be 35 GW_e.

15/00376 Evaluation of ground source absorption heat pumps combined with borehole free cooling

Wu, W. *et al. Energy Conversion and Management*, 2014, 79, 334–343.

Ground source absorption heat pumps (GSAHPs) extract less heat from the ground than ground source electrical heat pumps (GSEHPs) and therefore require fewer boreholes and can reduce the deterioration in heating performance. GSAHP integrated with borehole free cooling is proposed to reduce the thermal imbalance further and keep the heat pump system working efficiently for a longer period. Dynamic simulations of different applications in three typical cities are conducted in TRNSYS to investigate the potential of GSAHP + borehole free cooling. The results show that the soil temperature reduction for GSAHP can reach 6–7 °C after 10 years but can be reduced to 0–3 °C by floor radiation cooling, and the coefficient of performance and heating capacity can be kept at a high level. Moreover, the unguaranteed heating hours can be greatly reduced, while the guaranteed cooling hours are in the range of 800–1500 in different areas. Additionally, the primary energy efficiency of GSAHP with heating only is 95–120%, while that of the hybrid GSAHP + borehole free cooling can reach 111–156% in typical cities. The proposed system provides additional cooling and indoor comfort while also reducing the underground thermal imbalance, slowing the deterioration of soil temperature and system performance, improving the heating reliability, and reducing the system's energy consumption.

15/00377 Experimental method for determining mixed-phase precipitation kinetics from synthetic geothermal brine

Banks, B. *et al. Applied Geochemistry*, 2014, 47, 74–84.

A batch reactor design for determining precipitation kinetics from an experimental (i.e. laboratory made) geothermal brine is presented. The purpose of the method is to improve techniques for predicting scaling risks in basin-hosted, enhanced geothermal systems. The method is applied to determining kinetic rate laws for alkali-earth metal sulfate precipitation in the Na–Ca–Ba–Sr–Cl–SO₄–H₂O system, which are a set of components commonly found in sedimentary basin brines, worldwide. The method of integral rates was used to determine alkali-earth metal precipitation kinetic rate laws for solutions reacting over 4 h at 75 and 150 °C. At 75 °C, the rate law for total sulfate precipitation is rate = 0.0137 × [SO₄^{2−}]². At 150 °C, the rate law for total sulfate precipitation is rate = 0.011 × [SO₄^{2−}]². All precipitants are found to be barite, with minor amounts of calcium and strontium incorporated into the barite structure. If only barite precipitation is considered, the rate coefficients become 0.045 and 0.025 at 75 and 150 °C, respectively. The precipitants' specific reactive surface areas are estimated for each time step and temperature and are qualitatively observed to decrease as the reactions progress. The three parameters required to develop reactive transport models of mineral precipitation in a geothermal power plant are: (1) the reaction order, (2) the rate coefficient and (3) the change in specific reactive surface area over time. All three of these parameters can be determined with the method employed in this study. Results from these experiments confirm previous results that precipitation kinetics are dependent on both starting concentrations and background salinities. Experiments designed to predict scaling risks in real geothermal systems require adjustments to the method presented herein, specifically (1) experimental fluids must more closely approximate real geothermal brines,

(2) a larger reactor is required to produce a greater precipitant mass and (3) full quantitative assessment of the precipitants' specific reactive surface area are required to reduce the error of these measurements.

15/00378 General review of ground-source heat pump systems for heating and cooling of buildings

Sarbu, I. and Sebarchievici, C. *Energy and Buildings*, 2014, 70, 441–454.

A large number of ground-source heat pump (GSHP) systems have been used in residential and commercial buildings throughout the world due to the attractive advantages of high energy and environmental performances. The GSHPs are proven renewable energy technology for space heating and cooling. This paper provides a detailed literature review of the GSHP systems, and their recent advances. The operation principle and energy efficiency of a heat pump are defined first. Then, a general introduction on the GSHPs and its development, and a detailed description of the surface water, ground-water (GWHP), and ground-couplet (GCHP) heat pumps are performed. The most typical simulation and ground thermal response test models for the vertical ground heat exchangers currently available are summarized including the heat transfer processes outside and inside the boreholes. Also, some information about a new GWHP using a heat exchanger with special construction, and the possibility to obtain the better energy efficiency with combined heating and cooling by GCHP are presented. The various hybrid GCHP systems for cooling or heating-dominated buildings are well described. Finally, the energy, economic and environmental performance of a closed-loop GCHP system is also briefly reviewed. It is found that the GSHP technology can be used both in cold and hot weather areas and the energy saving potential is significant.

15/00379 Heating and cooling energy demand in underground buildings: potential for saving in various climates and functions

van Dronkelaar, C. *et al. Energy and Buildings*, 2014, 71, 129–136.

Underground buildings are pointed out as alternatives to conventional above-ground buildings for reducing total energy requirements, while alleviating land use and location problems. This paper investigates the potential in reducing the heating and cooling energy demand of underground buildings compared to above-ground buildings. Monthly calculations based on EN-ISO 13790 are performed to obtain the annual heating and cooling energy demand of aboveground and underground buildings for various climates, building functions and underground depths. Uncertainty of input parameters is considered in the calculation, and sensitivity analysis is carried out. Energy reduction is achievable for all climates and functions when underground and above-ground buildings, but the magnitude is related to the combination of different design elements. Results show that 11% of cases analysed can be considered near zero-energy buildings (annual energy demand less than 10 kWh/m²y). Sensitivity analysis indicates that the most influential parameters depend on the climate and building function. As expected, building functions with high internal gains perform better in cold climates, and the ones with low internal gains perform better in hot climates.

15/00380 Influences of soil hydraulic and mechanical parameters on land subsidence and ground fissures caused by groundwater exploitation

Chen, X.-x. *et al. Journal of Hydrodynamics, Ser. B*, 2014, 26, (1), 155–164.

In order to study the influences of hydraulic and mechanical parameters on land subsidence and ground fissure caused by groundwater exploitation, based on the Biot's consolidation theory and combined with the non-linear rheological theory of soil, the constitutive relation in Biot's consolidation theory is extended to include the viscoelastic plasticity, and the dynamic relationship among the porosity, the hydraulic conductivity, the parameters of soil deformation and effective stress is also considered, a three-dimensional full coupling mathematical model is established and applied to the study of land subsidence and ground fissures of Cangzhou in Hebei Province, China, through the analysis of parameter sensitivity, the influences of soil hydraulic and mechanical parameters on land subsidence and ground fissure are revealed. It is shown that the elastic modulus *E*, the Poisson ratio *ν*, the specific yield *μ* and the soil cohesion *C* have a great influence on the land subsidence and the ground fissures. In addition, the vertical hydraulic conductivity *K_v* and the horizontal hydraulic conductivity *K_h* also have a great influence on the land subsidence and the ground fissures.

15/00381 Investigations and model validation of a ground-coupled heat pump for the combination with solar collectors

Pärisch, P. *et al. Applied Thermal Engineering*, 2014, 62, (2), 375–381.

The operation of ground-coupled heat pumps in combination with solar collectors requires comprising knowledge of the heat pump behaviour under non-standard conditions. Especially higher temperatures and varying flow rates in comparison to non-solar systems have to

be taken into account. Furthermore the dynamic behaviour becomes more important. At the authors' institution, steady-state and dynamic tests of a typical brine/water heat pump have been carried out in order to analyse its behaviour under varying operation conditions. It has been shown, that rising source temperatures do only significantly increase the coefficient of performance, if the source temperature is below 10–20 °C, depending on the temperature lift between source and sink. The flow rate, which has been varied both on the source and the sink side, only showed a minor influence on the exergetic efficiency. Additionally a heat pump model for TRNSYS has been validated under non-standard conditions. The results are assessed by means of TRNSYS simulations.

15/00382 Minewater 2.0 project in Heerlen the Netherlands: transformation of a geothermal mine water pilot project into a full scale hybrid sustainable energy infrastructure for heating and cooling

Verhoeven, R. *et al. Energy Procedia*, 2014, 46, 58–67.

In the past 10 years numerous research and commercial initiatives have been undertaken in Europe to develop abandoned coal mining fields into low-temperature resources. One of the most successful is the Minewater project of the municipality of Heerlen, the Netherlands, where a low-temperature district heating system was launched in operation in October 2008, under the European Interreg IIB NWE programme and the Sixth Framework Program project EC-REMIN-ING-lowex. The Minewater project is now being upgraded from a straightforward pilot system to a full-scale hybrid sustainable energy structure called Minewater 2.0. A totally new concept which becomes an essential part of the sustainable energy structure plan of Heerlen and has the following landmarks: (a) energy exchange instead of energy supply; cluster grids for energy exchange between buildings and the existing mine water grid for energy exchange between cluster grids. (b) Energy storage and regeneration in mine water reservoirs instead of depletion. (c) Addition of poly-generation: bio-combined heat and power, solar energy, feed in of waste heat (data centres and industry), cooling towers for peak cold demands. Enlargement hydraulic and thermal capacity mine water grid through improving well pumps, pressure boosting systems and reuse of the existing mine water return pipe for additional supply and disposal of hot mine water. (d) Fully automatic and demand-driven supply of hot and cold mine water through usage of pressurized buffer systems at the extraction wells and sophisticated injections valves at the injection wells. And (e) all geographically dispersed mine water installations at buildings, clusters and wells are equipped with sophisticated process control units that communicate with a central monitoring system through the Internet. The first phase of the Minewater 2.0 project has been in operation since June 2013.

15/00383 Numerical simulation of electricity generation potential from fractured granite reservoir through a single horizontal well at Yangbajing geothermal field

Zeng, Y.-C. *et al. Energy*, 2014, 65, 472–487.

The development of a deep high-temperature heat reservoir at the Yangbajing geothermal field in China has a very important significance for capacity expanding and sustaining of ground power plants. The geological exploration found that there is a fractured granite heat reservoir with an average temperature of 248 °C at depth of 950–1350 m in well ZK4001 in the north of the geothermal field. In this work, a simplified conceptual model of the 950–1350 m reservoir is established based on all the existing geological data, and the electricity generation potential from this fractured granite reservoir by geothermal water mining through a single horizontal well is numerically simulated. The results indicate that the single horizontal well system attains an electric power of 3.23–3.48 MW and an energy efficiency of about 50.00–17.16 during 20 years under reference conditions. The main parameters that affect the heat extraction and electricity generation are reservoir porosity, permeability and water production rate. Higher porosity or higher permeability or higher water production rate will be favourable for improving the electricity generation performance, under the precondition of not arousing vaporization and precipitation in the liquid water saturated reservoir.

15/00384 Parametric optimization and range analysis of organic Rankine cycle for binary-cycle geothermal plant

Wang, X. *et al. Energy Conversion and Management*, 2014, 80, 256–265.

In this study, a thermodynamic model of organic Rankine cycle (ORC) system combined with orthogonal design is proposed. The comprehensive scoring method was adopted to obtain a comprehensive index to evaluate both of the thermodynamic performance and economic performance. The optimal level constitution of system parameters which improves the thermodynamic and economic performance of ORC system is provided by analysing the result of orthogonal design. The range analysis based on orthogonal design is adopted to determine the sensitivity of system parameters to the net power output of ORC system, thermal efficiency, the size parameter factor of radial inflow

turbine, the power decrease factor of the pump and the total heat transfer capacity. The results show that the optimal level constitution of system parameters is determined as the working fluid of R245fa, the super heating temperature of 10 °C, the pinch temperature difference in evaporator and condenser of 5 °C, the evaporating temperature of 65 °C, the isentropic efficiency for the pump of 0.75 and the isentropic efficiency of radial inflow turbine of 0.85. The order of system parameters' sensitivity to the comprehensive index of orthogonal design is evaporating temperature > isentropic efficiency of radial inflow turbine > the working fluid > the pinch temperature difference of the evaporator and the condenser > isentropic efficiency of cycle pump > the super heating temperature. This study provides useful references for selecting main controlled parameters in the optimal design of ORC system.

15/00385 The research on ring-coil heat transfer models of pile foundation ground heat exchangers in the case of groundwater seepage

Zhang, W. *et al. Energy and Buildings*, 2014, 71, 115–128.

This paper presents a mathematical model for describing heat transfer around the pile foundation ground heat exchangers (GHEs) when seepage of groundwater imposes an effect on the heat exchange process. The corresponding analytical solutions on temperature response are acquired based on combined heat transfer case; the model take the spiral coils arrangement and their pitches inside piles into consideration and identify the differences between the new models and those former models which did not treat spiral tube as a series of separate coils along the *z*-axial direction. The influence exerted on temperature response by every parameter was investigated. Two cases were compared, i.e. pure conduction and combined heat transfer including both conduction and convection. The relevant calculations prove that the heat transfer efficiency between pile foundation GHEs and the surrounding underground medium can be improved especially when some parameters attain a certain extent. The research on new models can help boost the development of energy pile technology.

Solar energy

15/00386 An empirical study of performance characteristics of BIPV (building integrated photovoltaic) system for the realization of zero energy building

Lee, J. B. *et al. Energy*, 2014, 66, 25–34.

This study analysed the performance characteristics of building integrated photovoltaic (BIPV) systems of the Climate Change Research Building of National Environment Research Institution in Korea which was designed with the aim of being a zero-carbon building. This building, with an area of 2449 m² consists of five laboratories, performance ratio department, conference room and others, and the area of conditioned space is 1668 m². In addition, the remaining residual load was predicted to 99,200 kWh when load reducing systems were applied such as insulation, an exterior shading device and lighting control. The BIPV system, which consists of three modules, glass to glass, glass to Tedlar/crystal and amorphous, has 116.2 kWp of total capacity, and is applied to the walls, windows, atrium and pagoda on roof. After the completion of building, the total amount of energy consumption and the gross generation of BIPV system were 104602.4 and 105266.6 kWh through a year from April 2011 to March 2012, respectively. It was evaluated to achieve zero-carbon building because the energy surplus was 664.2 kWh.

15/00387 An innovation-focused roadmap for a sustainable global photovoltaic industry

Zheng, C. and Kammen, D. M. *Energy Policy*, 2014, 67, 159–169.

The solar photovoltaic (PV) industry has undergone a dramatic evolution over the past decade, growing at an average rate of 48% per year to a global market size of 31 GW in 2012, and with the price of crystalline-silicon PV module as low as \$0.72/W in September 2013. To examine this evolution. A comprehensive dataset from 2000 to 2012 was built for the PV industries in the USA, China, Japan and Germany, which was used to develop a model to explain the dynamics among innovation, manufacturing, and market. A two-factor learning curve model was constructed to make explicit the effect of innovation from economies of scale. The past explosive growth has resulted in an oversupply problem, which is undermining the effectiveness of 'demand-pull' policies that could otherwise spur innovation. The next era of solar PV deployment and a sustainable PV industry will rely increasingly on an innovation-focused roadmap that will focus on incentivizing innovation in the medium term. Once the PV technology is largely cost-competitive with conventional electricity sources after the next 7–10 years of an innovation-driven phase, the PV industry can

self-expand without major policy interventions under the reinforcing dynamics among cost reduction, market growth, and economies of scale.

15/00388 An integrated approach to evaluate the performance of solar water heater in the urban environment
Li, D. and Liao, S. *Energy and Buildings*, 2014, 69, 562–571.

Solar water heaters (SWHs) are increasingly used in urban areas where the collectors are liable to be shaded by nearby buildings, however, the effect of nearby buildings on the behaviour of SWHs has not yet been understood well. This paper presents an integrated approach to quantitatively evaluate the performance of SWHs in the obstructed scenes of arbitrary geometric complexity by coupling the radiation model in the urban resource flow tool CitySim with the SWH model developed in TRNSYS. A case study is conducted to illustrate the effect of the obstructions on daily and annual thermal performance and annual primary energy consumption of SWH. The results from the case study reveal that the SWH with typical configurations in the obstructed context may consume more primary energy than conventional water heater does, however this is not the case for the SWH in the unobstructed context. Fortunately, using the proposed approach can effectively avoid this problem. Thus, the proposed approach is useful for making better use of SWH in the urban context to maximize energy saving.

15/00389 Assessing the effects of customer innovativeness, environmental value and ecological lifestyles on residential solar power systems install intention

Chen, K. K. *Energy Policy*, 2014, 67, 951–961.

To understand the impact of environmental value, ecological lifestyle, customer innovativeness on customer intention to install solar power system (SPS) in their private houses, an empirical model was proposed. Customer innovativeness was treated as a second-order construct with two first-order dimensions, with each of the latter being measured by means of reflective indicators. Using structural equation modelling, data collected from 203 college students and faculties at a University of Taiwan were tested against the model. It was found that environmental value has a positive impact on ecological lifestyle and SPS install intention. Although ecological lifestyle associates positively with SPS install intention, the effect disappears when environmental value is included in the model. The effect of customer innovativeness on SPS install intention results from the tendency of customer novelty seeking, while the impact of customer independent judgement-making on SPS install intention is insignificant. The model explained 76% of the total variations within SPS install intention. Managerial implications for promoting of SPS are considered, and suggestions for further research provided.

15/00390 Battery capacity determination with respect to optimized energy dispatch schedule in grid-connected photovoltaic (PV) systems

Gitizadeh, M. and Fakhrazadegan, H. *Energy*, 2014, 65, 665–674.

This paper describes an approach to optimize the capacity of battery used in a grid-connected photovoltaic system (PV/storage system). The scheduling of the battery after installation has to be considered for the optimal design, because battery degradation cost is mainly a function of system operation. In this paper, peak shaving and load shifting, which are important applications of PV/storage systems, are studied. Load shifting is mostly implemented when time-of-use pricing is in effect and peak shaving is beneficial when utility customers are charged for peak demand prices. In order to account for seasonality in system net load, data clustering techniques are implemented to produce scenarios for the net load of the customer. Then, the proposed mixed integer programming model of the optimization problem is solved. To illustrate the important cost of battery degradations, a model of non-ideal battery is also studied and the results are compared with the case which ideal model of battery is used. Results show that sizing determination of the battery highly depends on the exact pricing structure. In addition, it is illustrated that, considering real assumptions for battery ageing is necessary to reliably estimate financial benefits of storages in PV/storage systems.

15/00391 Calculation of the cost-effectiveness of a PV battery system

Bruch, M. and Müller, M. *Energy Procedia*, 2014, 46, 262–270.

A possible way to calculate the cost-effectiveness of a photovoltaic (PV) system combined with electric energy storage for a household is presented in this paper. To evaluate the electricity costs, of the PV–battery system, the progression of the power demand and electricity production is evaluated and compared with cost and revenue of the resulting energy flow based on the electricity purchase prices and the German Renewable Energy Act (EEG) bonus for the feed in of renewable solar energy. The results show that solar applications with electricity storages can be profitable. But the high purchase price of the

storage reduces the financial gain of the PV system. This paper also reveals that in the examined case redox flow batteries are the most promising technology and lead-acid batteries are more lucrative than lithium-ion batteries due to their lower initial costs. The calculation can predict the cost-effectiveness of a solar system with energy storage and therefore help to find the best battery size for a certain household.

15/00392 Distributed photovoltaic generation in Brazil: an economic viability analysis of small-scale photovoltaic systems in the residential and commercial sectors

Holdermann, C. *et al. Energy Policy*, 2014, 67, 612–617.

This paper examines the economic viability of small-scale, grid-connected photovoltaics (PVs) in the Brazilian residential and commercial sectors after the introduction of the net metering regulation in April 2012. This study uses the discounted cash flow method to calculate the specific investment costs that are necessary for photovoltaic systems to be economically viable for each of the 63 distribution networks in Brazil. In the calculation, the authors utilized the current electricity tariffs, including fees and taxes, which were obtained through telephone interviews and publicly available information. The authors obtained a second important parameter by simulating PV-systems with the programme PV*Sol at the distribution company headquarters' locations. In the base-case scenario that reflected the current situation, in none of the distribution networks was PVs economically viable in either the commercial or residential sectors. The authors improved the environment for grid-connected PVs in the scenarios by assuming both lower PV-system costs and a lower discount rate to determine the effect on photovoltaics viability.

15/00393 Energy performance of different photovoltaic module technologies under outdoor conditions

Cañete, C. *et al. Energy*, 2014, 65, 295–302.

A comparative study is performed to obtain the energy performance of four different photovoltaic module technologies, when they are exposed to the same real sun conditions over a one-year period under the meteorological conditions of southern Spain. Modules of thin film technologies were analysed: amorphous silicon (a-Si), tandem structure of amorphous silicon and microcrystalline silicon (a-Si/ μ c-Si) and cadmium telluride (CdTe). In addition, a polycrystalline silicon module (pc-Si) was studied. The modules were characterized by measuring their I – V curve. Thin film modules show changes of the peak power at standard test conditions throughout the year. This variation is more remarkable in a-Si modules. The performance comparison shows that the performance of thin film modules is better than that of pc-Si modules for this location. However, CdTe and pc-Si modules present better performances during the winter months with higher daily yield values and lower total losses, while a-Si and a-Si/ μ c-Si modules perform better in summer. This paper also presents an empirical model that allows the daily energy performance of different module technologies to be calculated according to the daily irradiation and to the daily average temperature of the module. The proposed empirical model has an average relative error under 5% for all analysed modules.

15/00394 Exergo-economic analysis of a solar driven hybrid storage absorption refrigeration cycle

Siddiqui, F. R. *et al. Energy Conversion and Management*, 2014, 80, 165–172.

This paper presents the exergo-economic analysis of a 5 kW refrigeration cycle with hybrid storage system. The novel hybrid storage comprises a cold (ice) storage tank, an ammonia storage tank, a weak solution tank and a strong solution tank to suffice the night-time cooling load. The exergo-economic analysis is performed to compare the components of the refrigeration cycle based on the costs of initial capital investment and the costs of irreversibilities. The components of the refrigeration cycle are evaluated and compared using exergo-economic variables such as the relative cost difference, exergy destruction cost rate and exergo-economic factor. The effect of generator temperature, condenser temperature and evaporator temperature on the exergetic efficiency of the system is also studied. The paper also presents a quasi-steady exergy and exergo-economic analysis for a representative summer day of Dhahran region. This study can be further used in the optimization of design variables of the studied refrigeration cycle.

15/00395 Experimental study of inlet structure on the discharging performance of a solar water storage tank

Li, S.-h. *et al. Energy and Buildings*, 2014, 70, 490–496.

Using a solar water heating system can reduce the conventional energy consumption of a building. A good inlet of the solar storage tank can enhance the thermal stratification and improve the thermal storage efficiency and discharging efficiency. Experiments were carried out to investigate the discharging performance of a rectangular storage tank with different inlet structures which were slotting-type inlet, direct inlet and shower-type inlet. This study aimed to provide guidance for the optimization of the inlet structure of water tank so that the efficiency of

solar water heating system could be improved further. The effective discharging efficiency and effective discharging time were introduced to evaluate the performance of water tank with different inlet structures. The results showed that the slotting-type inlet exhibited the best thermal stratification and improved the discharging performance of the tank more effectively than the other two inlets. Energy saving potential of new inlet was also presented.

15/00396 Experimental study on the combined effects of inclination angle and insert devices on the performance of a flat-plate solar collector

Sandhu, G. et al. *International Journal of Heat and Mass Transfer*, 2014, 71, 251–263.

This study reports an experimental investigation into the thermal performance of a flat-plate solar collector using insert devices, over a Reynolds number range 200–8000 and a Prandtl number range of 5–8, using water as the working fluid. A variety of conventional and novel insert configurations were considered which include, twisted-tape inserts, wire coil inserts and wire mesh insert. The results clearly indicate the enhancement of the Nusselt number by all insert devices. Comparison of the best inserts from different insert families show that in the laminar flow regime, the mesh insert performed the best whereas, the concentric coils achieved the highest Nusselt number augmentation in the turbulent regime, relative to the smooth pipe with no inserts. From the practical aspects, concentric coils were recommended as the best insert among those tested, which shows an overall Nusselt number enhancement of 110% in the low Reynolds number range and 460% in the high Reynolds number range. The impact of collector inclination of the performance of these insert devices was also investigated. The results show that the channel inclination does not have a significant impact on the Nusselt number enhancement.

15/00397 Impacts of residential photovoltaic power fluctuation on on-load tap changer operation and a solution using DSTATCOM

Yan, R. et al. *Electric Power Systems Research*, 2014, 111, 185–193. Recently penetration of photovoltaic (PV) systems in low voltage (LV) distribution networks has drastically increased. The stochastic nature of PV output coupled with the characteristic of high R/X ratio of LV distribution network results in a direct correlation between PV power and voltage fluctuations. Currently distribution networks rely heavily on existing on load tap changing (OLTC) transformers to mitigate voltage fluctuations. However, during the regulation process OLTC transformers can experience excessive tap changing with high PV penetration, which in turn results in an increased maintenance requirement and shorter lifetime. Without the knowledge of how an increase in PV penetration impacts the operation of an OLTC, a distribution network operator (DNO) cannot effectively coordinate compensation. This paper examines the effect of PV penetration levels on OLTC transformers and voltage regulation. The investigation of tap changing frequencies and voltage profiles is done through quasi-static time-series simulations using a residential street network and one year real world data obtained from local DNOs and research institutes. Then, a mitigation strategy is developed using a Distribution Static Compensator (DSTATCOM) and interaction between OLTC and DSTATCOM is also analysed. This will enable DNOs to choose an appropriate size of DSTATCOM based on economic and technical requirements of voltage regulation.

15/00398 Modeling, performance analysis and economic feasibility of a mirror-augmented photovoltaic system

Fortunato, B. et al. *Energy Conversion and Management*, 2014, 80, 276–286.

In the past few years, solar photovoltaic (PV) systems have had great impetus with research and demonstration projects, both in Italy and other European countries. The main problems with solar PVs are the cost of solar electricity, which is still higher compared with other renewables (such as wind or biomass), due to the cost of semiconductors, and the low conversion efficiency. However, PV panel prices are rapidly decreasing benefiting from favourable economies of scale. For instance, according to the Energy Information Administration the US average levelized costs for plants entering service in the 2018 should be \$144.3/MWh for solar PV, whereas \$111.0/MWh for biomass and \$86.6/MWh for wind. In order to increase the electric yield of PV modules (which can be even doubled with respect to constant tilt configurations), without significantly increasing the system costs, it was decided to consider the addition of inclined mirrors at both sides of the PV modules, so as to deflect more solar rays towards them, as in mirror-augmented photovoltaic (MAPV) systems. The system preserves its constructive simplicity with commercial flat PV modules even though dual axis tracker must be implemented, since MAPV systems harness mainly the direct radiation. The performance analysis of MAPV systems starts from the calculation of the global irradiation on the surface of the PV module which is a sum of the direct sunlight

on it and the irradiation reflected by the mirrors. A mathematical model of a MAPV system is presented, which takes into account not only the increase of direct (or beam) radiation, due to the mirrors, but also the reduction of both the diffuse and reflected radiations due to the shadowing effect of the flat mirrors. In particular, under an isotropic sky assumption, a simplified analytical expression, applicable in the case of MAPV systems, for the sky-view factor has been developed. The deterioration in the performance of the PV system as a result of the increasing cell temperature with radiation augmentation due to mirrors has been also evaluated. Moreover, in order to provide a more realistic view of the process, the energy analysis is accompanied by the exergy analysis. Finally, in order to analyse the economics of MAPV systems, net present value, discounted payback period, internal rate of return and life-cycle costs, have been considered and compared with both a constant tilt building-integrated photovoltaic system and a system with a dual axis tracker.

15/00399 Optimisation of functionally graded material thermoelectric cooler for the solar space power system

Gasik, M. and Bilotsky, Y. *Applied Thermal Engineering*, 2014, 66, (1–2), 528–533.

New solar space power system (SSPS) is designed for harvesting solar energy in space and its conversion and transmission to the Earth using laser radiation. This laser system needs to be kept within constant temperature range and the cooling system should have no moving parts, which makes a Peltier device (thermoelectric cooling; TEC) to be a viable option. The challenge of the TEC system is low coefficient of performance and need of a huge radiator to dissipate excess low-grade heat into the space. The present study analyses and optimizes the TEC system for SSPS with use of functionally graded material (FGM) semiconductors. The performance of FGM semiconductors is calculated against set of objectives and constraints, taking into account temperature-dependent properties. Application of FGM vs homogeneous TEC materials allows increase of coefficient of performance by several times, halving current to form-factor ratio.

15/00400 Optimization of antireflection multilayer for industrial crystalline silicon solar cells

Sahouane, N. and Zerga, A. *Energy Procedia*, 2014, 44, 118–125.

Reflection of the incident photons by the silicon surface is a major source of losses during photovoltaic conversion. However, these losses can be minimized by depositing an antireflection layer, usually silicon nitride SiNx:H , combined with an appropriate texturing. This layer should also provide a good passivation where a real dilemma can be arising. In contrast the surface passivation gets better with increasing Si content (large optical index for $n > 2.3$) and the minimum reflectivity was found for small optical index. To achieve this, one first approach consists to use a double antireflective layer with two materials of different refractive index n . Among the materials that are appropriate from the standpoint of physics and technology are SiNx:H -rich silicon, oxynitride SiO_xN_y and silicon oxide SiO_2 . To optimize the antireflection multilayer, the authors have developed a numerical simulation code with Matlab software package where the method of transfer matrix was used to solve the optical equation. These solutions permit us to plot the optical reflectivity and the absorption versus wavelengths and layer thicknesses. The optical refractive index and thicknesses of considered materials, which allowed us to have the lowest reflection, were used to simulate the electrical properties of the cell with PC1D and Silvaco software. Thus, the results showed the cell efficiency increase by 0.3% and effective reflectivity of 7.4% is obtained with a first oxide layer ($n_1 = 1.5$ and $d_1 = 55$ nm), and a second layer of silicon nitride ($n_2 = 2.1$ and $d_2 = 53$ nm) non-encapsulated compared to a reference solar cell (with a SARC SiN). In the case of multilayer non-encapsulated, the optimization has shown that it is possible to increase the efficiency by 0.7% with the refractive index (1.48, 2 and 2.4) and thicknesses (80, 5 and 50) nm.

15/00401 Ordered mesoporous carbon-decorated reduced graphene oxide as efficient counter electrode for dye-sensitized solar cells

Sun, W. et al. *Carbon*, 2014, 77, 18–24.

Due to the advantages of both rapid electron transport of reduced graphene oxide (rGO) sheet and high catalytic performance of ordered mesoporous carbon (OMC), composites of OMC with rGO (G@OMC) have been prepared through the hard-template approach and used as efficient counter-electrode (CE) materials for dye-sensitized solar cells (DSSCs). When compared with pure OMC, the as-obtained G@OMC composites exhibit a higher electrocatalytic activity for the reduction of triiodide, owing to the synergetic effect between rGO and OMC. As a consequence, the DSSCs assembled with this G@OMC CE show an improved photovoltaic conversion efficiency of 6.38% compared with 5.67% for DSSCs assembled with OMC CE, which could compete with the efficiency (7.05%) produced by the Pt CE under the same conditions.

15/00402 Performance analysis of a Kalina cycle for a central receiver solar thermal power plant with direct steam generation

Modi, A. and Haglind, F. *Applied Thermal Engineering*, 2014, 65, (1–2), 201–208.

Solar thermal power plants have attracted increasing interest in the past few years – with respect to both the design of the various plant components, and extending the operation hours by employing different types of storage systems. One approach to improve the overall plant efficiency is to use direct steam generation with water/steam as both the heat transfer fluid in the solar receivers and the cycle working fluid. This enables operating the plant with higher turbine inlet temperatures. Available literature suggests that it is feasible to use ammonia-water mixtures at high temperatures without corroding the equipment by using suitable additives with the mixture. The purpose of the study reported here was to investigate if there is any benefit of using a Kalina cycle for a direct steam generation, central receiver solar thermal power plant with high live steam temperature (450°C) and pressure (over 100 bar). Thermodynamic performance of the Kalina cycle in terms of the plant exergy efficiency was evaluated and compared with a simple Rankine cycle. The rates of exergy destruction for the different components in the two cycles were also calculated and compared. The results suggest that the simple Rankine cycle exhibits better performance than the Kalina cycle when the heat input is only from the solar receiver. However, when using a two-tank molten-salt storage system as the primary source of heat input, the Kalina cycle showed an advantage over the simple Rankine cycle because of about 33% reduction in the storage requirement. The solar receiver showed the highest rate of exergy destruction for both the cycles. The rates of exergy destruction in other components of the cycles were found to be highly dependent on the amount of recuperation, and the ammonia mass fraction and pressure at the turbine inlet.

15/00403 Securitization of residential solar photovoltaic assets: costs, risks and uncertainty

Alafita, T. and Pearce, J. M. *Energy Policy*, 2014, 67, 488–498.

Limited access to low-cost financing is an impediment to high-velocity technological diffusion and high grid penetration of solar photovoltaic (PV) technology. Securitization of solar assets provides a potential solution to this problem. This paper assesses the viability of solar asset-backed securities (ABS) as a lower cost financing mechanism and identifies policies that could facilitate implementation of securitization. First, traditional solar financing is examined to provide a baseline for cost comparisons. Next, the securitization process is modelled. The model enables identification of several junctures at which risk and uncertainty influence costs. Next, parameter values are assigned and used to generate cost estimates. Results show that, under reasonable assumptions, securitization of solar power purchase agreements can significantly reduce project financing costs, suggesting that securitization is a viable mechanism for improving the financing of PV projects. The clear impediment to the successful launch of a solar ABS is measuring and understanding the riskiness of underlying assets. This study identifies three classes of policy intervention that lower the cost of ABS by reducing risk or by improving the measurement of risk: (i) standardization of contracts and the contracting process, (ii) improved access to contract and equipment performance data and (iii) geographic diversification.

15/00404 The doping effect of Italian feed-in tariffs on the PV market

Antonelli, M. and Desideri, U. *Energy Policy*, 2014, 67, 583–594.

In less than 6 years, Italy has become one of the leading markets for photovoltaic (PV) power plants and one of the countries in the world with the largest number of installations and installed peak power. Such a quick and large growth is due to a series of feed-in tariff schemes that have been uncapped until 2012. As a matter of fact, any size or any number of PV power plants could be installed during a period of three years. Since the feed-in tariffs are not paid by national taxes but are charged on the electricity bills, Italian energy users are now due to pay each year a surcharge of €9 billion on their energy bills. This paper aims at discussing this development by highlighting the benefits but also some significant drawbacks that the application of uncontrolled feed-in tariffs has produced.

15/00405 Thermal design guidelines of solar power towers

Rodríguez-Sánchez, M. R. *et al. Applied Thermal Engineering*, 2014, 63, (1), 428–438.

One of the main problems of solar power tower plants with molten salt as heat transfer fluid is the reliability of central receivers. The receiver must withstand high working temperatures, molten salt corrosion and important solar flux transients that lead to thermal stresses and fatigue. Despite these difficulties, it is necessary an estimation of the receiver thermal efficiency in order to have an accurate estimation of the investment cost of the solar plant and to assure the lifetime estimation of the receiver. A thermal, mechanical and hydrodynamic analysis of

these receivers has been developing in this work, assuming constant heat flux in each axial discretized section of the tube wall but considering circumferential temperature variations in the perimeter of the tubes caused by the difference between the heat flux received by the front part of the tubes and by the rear part. The thermal analysis shows that the radiation losses are higher than in literature, and consequently the thermal efficiency is lower too. This is due to the fact that the effective tube wall temperature for radiation is higher than the mean tube wall temperature, especially if the rear temperature of the tubes is considered. Besides, it has been found that the highest temperatures and thermal stresses are sited on the eastern and western panels of the receivers. Film temperature is the most limiting parameter for the receiver design due to it is responsible for salt decomposition and tube corrosion. Therefore, once the tube material is chosen, the film temperature cannot exceed a critical value over which the corrosion ratio raises rapidly. Small tube diameters and low number of panels results in low film temperatures, although this kind of design increases the pressure drop. Therefore, a compromise between film temperature and pressure drop can lead to a receiver design that ensures its lifetime, and at the same time, optimizes the investment and operational cost of the receiver.

15/00406 Wind dependence of energy losses from a solar gas reformer

Liovic, P. *et al. Applied Thermal Engineering*, 2014, 63, (1), 333–346.

The thermal performance of a cavity receiver design for the CSIRO solar gas reformer is studied using transient computational fluid dynamics simulations. Under process control-induced operating conditions targeting constant internal wall temperatures, energy losses from the cavity nearly double for high-wind conditions as compared to no-wind conditions. Receiver geometry, inner cavity wall temperature and wind interact to result in differences in energy losses under steady wind velocities that can differ up to 40% depending on wind direction. The findings in this paper are useful for targeting improvements in receiver design and solar flux control during solar reactor operation.

Wind energy

15/00407 Adaptive neuro-fuzzy optimization of wind farm project net profit

Shamshirband, S. *et al. Energy Conversion and Management*, 2014, 80, 229–237.

A wind power plant which consists of a group of wind turbines at a specific location is also known as wind farm. To maximize the wind farm net profit, the number of turbines installed in the wind farm should be different in depend on wind farm project investment parameters. In this paper, in order to achieve the maximal net profit of a wind farm, an intelligent optimization scheme based on the adaptive neuro-fuzzy inference system (ANFIS) is applied. As the net profit measures, net present value (NPV) and interest rate of return (IRR) are used. The NPV and IRR are two of the most important criteria for project investment estimating. The general approach in determining the accept/reject/stay in different decision for a project via NPV and IRR is to treat the cash flows as known with certainty. However, even small deviations from the predetermined values may easily invalidate the decision. In the proposed model the ANFIS estimator adjusts the number of turbines installed in the wind farm, for operating at the highest net profit point. The performance of proposed optimizer is confirmed by simulation results. Some outstanding properties of this new estimator are online implementation capability, structural simplicity and its robustness against any changes in wind farm parameters. Based on the simulation results, the effectiveness of the proposed optimization strategy is verified.

15/00408 Can the regulated market help foster a free market for wind energy in Brazil?

Dalbem, M. C. *et al. Energy Policy*, 2014, 66, 303–311.

Wind energy has been negotiated in Brazil's regulated market through auctions organized by the government. Bilateral negotiations in the free market have been scarce. In 2011 wind farms were allowed to bid in 'A minus 5 (A – 5)' auctions, for energy with first delivery date 5 years ahead. This new design was expected to stimulate negotiations in the free market, as the 20-year contract in the regulated market eases financing while the 5-year grace period grants wind farms the option to sell whatever energy is generated beforehand in the free market. The authors modelled bidders' price decision in A – 5 auctions as real options and concluded that given the low prices averaging US\$50/MWh, winners are tempted to defer investment, expecting more favourable equipment and energy prices, or a better knowledge of the wind site. Construction is likely to begin in 2–3 years, with little time left for the free market. Bidders that consider the option of eventually

abandoning the project are more price competitive, increasing chances that some wind farms will never materialize. Therefore, this attempt to foster the free market may not pay-off and, moreover, it may have the unfavourable effect of turning Brazil's energy expansion planning a more difficult task.

15/00409 Dynamic modeling and optimal control of DFIG wind energy systems using DFT and NSGA-II

Zamanifar, M. *et al. Electric Power Systems Research*, 2014, 108, 50–58.

Once a doubly-fed induction generator (DFIG) is subjected to a disturbance by a change in the wind speed, the stator flux cannot change instantly. Under this condition, rotor back-electromotive force voltages reflect the effects of stator dynamics on rotor current dynamics, and have an important role on the oscillations of the rotor current. These oscillations decrease the DFIG system reliability and gear lifetime. Moreover, by focusing only on small signal analysis, the dynamic damping performance immediately following such disturbances is often degraded. Additional improvement in performance will be achieved if discrete Fourier transform (DFT) is used to quantify damping characteristic of the rotor current during changes of the operating points. This paper introduces an optimization technique based on non-dominated sorting genetic algorithm-II (NSGA-II) incorporating DFT analysis to achieve better control performance for DFIG system stability. Considering small signal stability, the main purpose of the control system in the present paper is to increase the system damping ratio as well as to guarantee enough stability margin. Eigenvalue analysis and time-domain simulations have been presented to demonstrate that the proposed optimizing method yields better control performance in comparison with one designed using mere eigenvalue relocation.

15/00410 Effect of wind generation system types on micro-grid (MG) fault performance during both standalone and grid connected modes

Kamel, R. M. *Energy Conversion and Management*, 2014, 79, 232–245. There are three wind generation (WG) system types. The first type is called the fixed speed wind generation (FSWG) system, which employs squirrel cage induction generators. The double-fed induction generator (DFIG) is utilized in the second type. The third type is called the full converter wind generation (FCWG) system, which is interfaced with a micro-grid (MG) through a back-to-back converter. During fault occurrence, each WG has its performance and characteristics determined by the generator physical characteristics and the MG earthing system configuration. For some WG types, the fault current depends also on the control algorithm of the power converter. The main target of this paper is to investigate and estimate how the fault performance of MG during both standalone and grid-connected modes is influenced by the type of WG. It is found during standalone mode that the type of the employed WG has a dominant impact on the MG performance under fault disturbance. On the contrary, the type of the employed WG has a negligible effect on the MG fault performance during grid-connected mode. This is because the main grid contributes most of the fault current. Effects of earthing system type on MG performance are highlighted.

15/00411 Evaluation of power flow solutions with fixed speed wind turbine generating systems

Haque, M. H. *Energy Conversion and Management*, 2014, 79, 511–518. An increased penetration of wind turbine generating systems into power grid calls for proper modelling of the systems and incorporating the model into various computational tools used in power system operation and planning studies. This paper proposes a simple method of incorporating the exact equivalent circuit of a fixed speed wind generator into conventional power flow program. The method simply adds two internal buses of the generator to include all parameters of the equivalent circuit. For a given wind speed, the active power injection into one of the internal buses is determined through wind turbine power curve supplied by the manufacturers. The internal buses of the model can be treated as a traditional P - Q bus and thus can easily be incorporated into any standard power flow program by simply augmenting the input data files and without modifying source codes of the program. The effectiveness of the proposed method is then evaluated on a simple system as well as on the IEEE 30- and 118-bus systems. The results of the simple system are also compared with those found through Matlab/Simulink using dynamic model of wind generating system given in SimPowerSystems blockset.

15/00412 Permanent magnet synchronous generator design solution for large direct-drive wind turbines: thermal behavior of the LC DD-PMSG

Alexandrova, Y. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 554–563.

Wind is one of the most compelling forms of indirect solar energy. Available now, the conversion of wind power into electricity is and will continue to be an important element of energy self-sufficiency planning. This paper is one in a series intended to report on the development of a new type of generator for wind energy; a compact, high-power, direct-drive permanent magnet synchronous generator (DD-PMSG) that uses direct liquid cooling (LC) of the stator windings to manage Joule heating losses. The main parameters of the subject LC DD-PMSG are 8 MW, 3.3 kV and 11 Hz. The stator winding is cooled directly by deionized water, which flows through the continuous hollow conductor of each stator tooth-coil winding. The design of the machine is to a large degree subordinate to the use of these solid-copper tooth-coils. Both steady-state and time-dependent temperature distributions for LC DD-PMSG were examined with calculations based on a lumped-parameter thermal model, which makes it possible to account for uneven heat loss distribution in the stator conductors and the conductor cooling system. Transient calculations reveal the copper winding temperature distribution for an example duty cycle during variable-speed wind turbine operation. The cooling performance of the liquid cooled tooth-coil design was predicted via finite element analysis. An instrumented cooling loop featuring a pair of LC tooth-coils embedded in a lamination stack was built and laboratory tested to verify the analytical model. Predicted and measured results were in agreement, confirming the predicted satisfactory operation of the LC DD-PMSG cooling technology approach as a whole.

15/00413 Proposal for an innovative chord distribution in the Troposkien vertical axis wind turbine concept

Bedon, G. *et al. Energy*, 2014, 66, 689–698.

An innovative design for the Troposkien concept is introduced by means of an advanced chord distribution, computed using the 'Weatherly Optimization Method for Blades of Air Turbines' (WOMBAT) algorithm for the performance optimization of vertical axis wind turbines. Five rotor blade architectures, characterized by a constant value of the thickness-to-chord ratio and a varying chord length along the blade span, are evaluated. The optimization process is conducted with respect to the power coefficient for a target wind speed of 9 m/s, obtaining a consistent improvement of rotor performance with respect to the baseline blade configuration.

15/00414 The impact of wind power generation on the electricity price in Germany

Ketterer, J. C. *Energy Economics*, 2014, 44, 270–280.

This paper investigates the relationship between intermittent wind power generation and electricity price behaviour in Germany. Using a GARCH model, the effect of wind electricity generation on the level and the volatility of the electricity price in an integrated approach was evaluated. The results show that variable wind power reduces the price level but increases its volatility. This paper's results also indicate that regulatory change has stabilized the wholesale price. The electricity price volatility has decreased in Germany after a modification of the marketing mechanism of renewable electricity. This gives confidence that further adjustments to regulation and policy may foster a better integration of renewables into the power system.

15/00415 The role of demand response in single and multi-objective wind-thermal generation scheduling: a stochastic programming

Falsafi, H. *et al. Energy*, 2014, 64, 853–867.

This paper focuses on using demand response (DR) as a means to provide reserve in order to cover uncertainty in wind power forecasting in smart grid environment. The proposed stochastic model schedules energy and reserves provided by both of generating units and responsive loads in power systems with high penetration of wind power. This model is formulated as a two-stage stochastic programming, where first-stage is associated with electricity market, its rules and constraints and the second-stage is related to actual operation of the power system and its physical limitations in each scenario. The discrete retail customer responses to incentive-based DR programmes are aggregated by demand response providers (DRPs) and are submitted as a load change price and amount offer package to independent system operator. Also, price-based DR programme behaviour and random nature of wind power are modelled by price elasticity concept of the demand and normal probability distribution function, respectively. In the proposed model, DRPs can participate in energy market as well as reserve market and submit their offers to the wholesale electricity market. This approach is implemented on a modified IEEE 30-bus test system over a daily time horizon. The simulation results are analysed in six different case studies. The cost, emission and multiobjective functions are optimized in both without and with DR cases. The multiobjective generation scheduling model is solved using augmented epsilon constraint method and the best solution can be chosen by entropy and 'technique for order preference

by similarity to ideal solution' (TOPSIS) methods. The results indicate demand side participation in energy and reserve scheduling reduces the total operation costs and emissions.

15/00416 Thermodynamic analysis of a hybrid thermal-compressed air energy storage system for the integration of wind power

Yang, Z. *et al. Applied Thermal Engineering*, 2014, 66, (1–2), 519–527. In China, a large amount of wind power is lost due to the difficulty of integrating fluctuating wind power into electricity grid systems. Advanced adiabatic compressed air energy storage (AA-CAES) is regarded as a promising emission-free technology to facilitate the wind power integration, but its high capital cost has hindered its wide commercialization. In the present work, a novel hybrid system was proposed on the basis of AA-CAES. It can reduce abandoned wind power and improve the financial return per capital cost of the system by increasing power output. In the new system, which is called hybrid thermal-compressed air energy storage (HTCAES), thermal energy storage (TES) units absorb the heat released from air compression and also the thermal energy converted from reluctant wind power using electrical heaters. Theoretical thermodynamic analyses show that the HTCAES system can absorb much more wind power than an AA-CAES system with the same scale of compressors, turbines, and TES units do. And recovery efficiency of this additional wind power is about 41–47%, depending on the final storage temperature of the TES. The power output ratio of the HTCAES system to the AA-CAES system increases with the maximum TES storage temperature and decreases with the operating pressure.

15/00417 Uncertainty modelling of wind turbine generating system in power flow analysis of radial distribution network

Das, B. *Electric Power Systems Research*, 2014, 111, 141–147. In this paper, interval arithmetic (IA) is used for taking into account the uncertainties of the active power produced by a wind turbine generating system (WTGS) in the power flow computation of a balanced radial distribution system. The effectiveness of the proposed method has been investigated by comparing the results obtained by this method with those obtained by Monte Carlo simulation (MCS) technique on two different balanced radial distribution systems. It has been found that the results obtained by these two methods (IA and MCS) are very close to each other while the computation time required by IA based method is significantly less than that required by MCS.

15/00418 Wind farms on undegraded peatlands are unlikely to reduce future carbon emissions

Smith, J. *et al. Energy Policy*, 2014, 66, 585–591. Onshore wind energy is a key component of the renewable energies used by governments to reduce carbon emissions from electricity production, but will carbon emissions be reduced when wind farms are located on carbon-rich peatlands? Wind farms are often located in uplands because most are of low agricultural value, are distant from residential areas, and are windy. Many UK uplands are peatlands, with layers of accumulated peat that represent a large stock of soil carbon. When peatlands are drained for construction there is a higher risk of net carbon loss than for mineral soils. Previous work suggests that wind farms sited on peatlands can reduce net carbon emissions if strictly managed for maximum retention of carbon. Here it is shown that, whereas in 2010, most sites had potential to provide net carbon savings, by 2040 most sites will not reduce carbon emissions even with careful management. This is due to projected changes in the proportion of fossil fuels used to generate electricity. The results suggest future policy should avoid constructing wind farms on undegraded peatlands unless drainage of peat is minimal and the volume excavated in foundations can be significantly reduced compared to energy output.

15/00419 Wind power idle capacity in a panel of European countries

Flora, R. *et al. Energy*, 2014, 66, 823–830. The volatility of the wind provokes the shortage of constant electricity generation. It determines the level of effective utilization of the installed capacity. In Europe, the decision to install wind-generating capacity has generally increased and has been eminently a decision of a political nature, strongly influenced by international commitments. However, the installation of additional wind capacity could be contributing to generating further idle capacity, which could be a concern economically, considering the inefficiency in the economic resources allocation. This paper sought to contribute to the debate about factors that are influencing wind power idle capacity. In particular, the focus is placed specifically on the role played by socio-economic factors and by the policymakers' measures, within a context of an energy mix using distinct sources of energy. Focused on a panel of European countries, for the time span 1998–2011, this study is able to capture the complexities where the phenomenon is evident, and for which a suitable number of observations are available. The pre-conditions of the panel techniques were exhaustively tested, and the

more suitable panel estimators led to outcomes with both robust and consistent results. It is proven that socio-economic factors should be considered in the global appraisal of the phenomenon of wind idle capacity. The results lead to an exciting consistency among these variables. Policy measures are indeed encouraging greater idle capacity, which is reinforced with the effect observed for the growth of installed capacity. Accordingly, international commitments must be sensitive to this effect. A policymakers' shift towards measures promoting the enhancement of technology efficiencies is strongly recommended in order to mitigate the phenomenon of idleness. With regard to conventional sources, the results strongly support that both the substitution effect and the lobbying effect impact on wind idle capacity, restraining it. In other words, these two effects could be smoothing larger idle capacity inefficiencies. As a result, the irreversible path towards renewables should be accompanied by the optimal contribution of conventional sources, in order to accommodate the economic inefficiencies of idleness at a reasonable cost. The way the wind and the conventional sources should evolve together in this path towards sustainable energy future deserves further research.

Others, including economics

15/00420 A top-down approach to assess physical and ecological limits of biofuels

de Castro, C. *et al. Energy*, 2014, 64, 506–512. The aim of this paper is to analyse the physical and ecological limits of biofuels (in particular, ethanol). To this end, three aspects are discussed. First of all, the territorial element, i.e. the real productivity of energy crops (in particular, ethanol), to show that, in general, the productivity is much lower than most of the literature on the subject suggests. Similarly, the authors then stress the high total territorial impact (the ecological footprint) associated with this kind of energy production. Thirdly, the authors offer data concerning the very modest nature of the energy balance of biofuels (energy returned on energy invested) and their real power density, considering the productivity of the crops grown for biofuel. As a comparison, these three aspects are estimated for other forms of energy, in particular, photovoltaic energy. The authors conclude that when the set of estimated parameters has been analysed, there exist reasonable doubts concerning the use of biofuels on a regional and global scale, so they should not, in principle, be promoted as a renewable energy source, nor is it desirable on such a scale.

15/00421 Biofuel subsidies versus the gas tax: the carrot or the stick?

Mazumder, D. B. *Energy Economics*, 2014, 44, 361–374. This paper provides an analytical framework to examine the relative efficiencies of a revenue-neutral biofuel subsidy and a gas tax in the presence of pre-existing distortions and growing substitutability between fuels. Both policies are set to achieve a targeted reduction in gasoline use at the state level. The model is then calibrated for a small open economy such as Illinois which is one of the largest producers of biofuels such as ethanol in the USA. The main result of the paper shows that raising the biofuel subsidy use reduces overall welfare by more than a higher gas tax, both aimed to achieve a targeted reduction in pure gasoline. The relative efficiency of the higher gas tax is primarily due to it exacerbating the pre-existing distortion in the biofuel market by less than the subsidy. Moreover, for current parameter estimates welfare improving policy combinations for achieving a targeted amount of energy security are higher gas taxes combined with lower biofuel subsidies and a lower tax on income. However, the preference for a gasoline-labour tax swap shrinks as the elasticity of substitution between the two fuels rises.

15/00422 Chance constrained programming using non-Gaussian joint distribution function in design of standalone hybrid renewable energy systems

Kamjoo, A. *et al. Energy*, 2014, 66, 677–688. Performance of a hybrid renewable energy system (HRES) is highly affected by changes in renewable resources and therefore interruptions of electricity supply may happen in such systems. In this paper, a method to determine the optimal size of HRES components is proposed, considering uncertainties in renewable resources. The method is based on chance-constrained programming (CCP) to handle the uncertainties in power produced by renewable resources. The design variables are wind turbine rotor swept area, photovoltaic panel area and number of batteries. The common approach in solving problems with CCP is based on assuming the uncertainties to follow Gaussian distribution. The analysis presented in this paper shows that this assumption may result in a conservative solution rather than an optimum one. The analysis is based on comparing the results of the

common approach with those obtained by using the proposed method. The performance of the proposed method in design of HRES is validated by using the Monte Carlo simulation approach. To obtain accurate results in Monte Carlo simulation, the wind speed and solar irradiance variations are modelled with known distributions as well as using time series analysis; and the best fit models are selected as the random generators in Monte Carlo simulation.

15/00423 Constrained optimal stochastic control of non-linear wave energy point absorbers

Sichani, M. T. *et al. Applied Ocean Research*, 2014, 47, 255–269.

The paper deals with the stochastic optimal control of a wave energy point absorber with strong non-linear buoyancy forces using the reactive force from the electric generator on the absorber as control force. The considered point absorber has only one degree of freedom, heave motion, which is used to extract energy. Constraints are enforced on the control force to prevent large structural stresses in the floater at specific hot spots with the risk of inducing fatigue damage, or because the demanded control force cannot be supplied by the actuator system due to saturation. Further, constraints are enforced on the motion of the floater to prevent it from hitting the bottom of the sea or to make unacceptable jumps out of the water. The applied control law, which is of the feedback type with feedback from the displacement, velocity, and acceleration of the floater, contains two unprovided gain parameters, which are chosen so the mean (expected value) of the power uptake in the stationary state is optimized. In order to ensure accuracy of the results for each configuration of the controller Monte Carlo simulations have been carried out for various sea-states and the final results have been presented in the paper. The effect of non-linear buoyancy force – in comparison to linear buoyancy force – and constraints of the controller on the power uptake of the device have been studied in details and supported by numerical simulations.

15/00424 Energy, exergy and exergoeconomic analyses of a combined renewable energy system for residential applications

Zafar, S. and Dincer, I. *Energy and Buildings*, 2014, 71, 68–79.

A hybrid renewable energy system is designed and analysed for electricity, hot water and hydrogen production. Exergy, energy and exergoeconomic analysis is conducted to determine the performance of the system under different operating and environmental conditions. The renewable energy system consisted of wind turbines and photovoltaic panels for electricity production operating an electrolyser which produced hydrogen. Hydrogen either goes directly to a fuel cell to produce electricity or through a compressor to run the fuel cell at high pressure. The heat from the fuel cell is used to heat water for domestic use. The analysis is conducted to determine the efficiencies of the system with and without domestic hot water heating and incorporating a compressor in the system. The analysis results suggested that approximately 14% energy and 21% exergy system efficiency increment is achieved when water is heated for domestic use. System involving the compressor lowered the overall system energy and exergy efficiencies. Decrease in efficiencies can be associated to the increase in hydrogen density, at high pressure states, which requires greater compressor work. The exergoeconomic study also suggested an improvement in the system when domestic water is heated using the excess heat from fuel cell.

15/00425 Establishing an agenda for social studies research in marine renewable energy

Kerr, S. *et al. Energy Policy*, 2014, 67, 694–702.

To date, academic research relating to marine renewable energy (MRE) has largely focused on resource assessment, technical viability and environmental impact. Experiences from onshore renewable energy tell us that social acceptability is equally critical to project success. However, the specific nature of the marine environment, patterns of resource distribution and governance means experiences from onshore may not be directly applicable to MRE and the marine environment. This paper sets out an agenda for social studies research linked to MRE, identifying key topics for future research: (i) economic impacts; (ii) wealth distribution and community benefits; (iii) communication and knowledge flow; (iv) consultation processes; (v) dealing with uncertainty; (vi) public attitudes and (vii) planning processes. This agenda is based on the findings of the first workshop of ISSMER, an international research network of social scientists with interests in marine renewable energy. Importantly, this research agenda has been informed by the experiences of developers, regulators and community groups in Orkney, UK. The Orkney archipelago, off the north coast of Scotland, is home to the most intense cluster of MRE research, development and deployment activity in the world today.

15/00426 Feasibility study and economic analysis of pumped hydro storage and battery storage for a renewable energy powered island

Ma, T. *et al. Energy Conversion and Management*, 2014, 79, 387–397.

This study examined and compared two energy storage technologies, i.e. batteries and pumped hydro storage (PHS), for the renewable energy powered microgrid power supply system on a remote island in Hong Kong. The problems of energy storage for off-grid renewable energy were analysed. The sizing methods and economic models were developed, and finally applied in the real project (case study). The results provide the most suitable energy storage scheme for local decision-makers. The two storage schemes were further divided into four options. Accordingly, the life-cycle costs (LCC), levelized costs for the renewable energy storage system and the LCC ratios between all options were calculated and compared. It was found that the employment of conventional battery (option 2) had a higher LCC value than the advanced deep cycle battery (option 1), indicating that using deep cycle batteries is more suitable for a standalone renewable power supply system. The pumped storage combined with battery bank option (option 3) had only 55% LCC of that of option 1, making this combined option more cost-competitive than the sole battery option. The economic benefit of pumped storage is even more significant in the case of purely pumped storage with a hydraulic controller (option 4), with the lowest LCC among all options at 29–48% of option 1. Sensitivity analysis demonstrates that PHS is even more cost competitive by controlling some adjustments such as increasing energy storage capacity and days of autonomy. Therefore, the renewable energy system coupled with pumped storage presents technically feasible opportunities and practical potential for continuous power supply in remote areas.

15/00427 Global energy storage demand for a 100% renewable electricity supply

Pleßmann, G. *et al. Energy Procedia*, 2014, 46, 22–31.

This study demonstrates – based on a dynamical simulation of a global, decentralized 100% renewable electricity supply scenario – that a global climate-neutral electricity supply based on the volatile energy sources photovoltaics (PV), wind energy (onshore) and concentrated solar power (CSP) is feasible at a reasonable cost. A central ingredient of this study is a sophisticated model for the hourly electric load demand in over 160 countries. To guarantee matching of load demand in each hour, the volatile primary energy sources are complemented by three electricity storage options: batteries, high-temperature thermal energy storage coupled with steam turbine, and renewable power methane (generated via the power to gas process) which is reconverted to electricity in gas turbines. The study determines – on a global grid with $1^\circ \times 1^\circ$ resolution – the required power plant and storage capacities as well as the hourly dispatch for a 100% renewable electricity supply under the constraint of minimized total system cost. Aggregating the results on a national level results in an levelized cost of electricity range of €80–200/MWh (on a projected cost basis for 2020) in this very decentralized approach. As a global average, €142/MWh are found. Due to the restricted number of technologies considered here, this represents an upper limit for the electricity cost in a fully renewable electricity supply.

15/00428 'Green' productivity growth in China's industrial economy

Chen, S. and Golley, J. *Energy Economics*, 2014, 44, 89–98.

This paper uses a directional distance function (DDF) and the Malmquist–Luenberger productivity index to estimate the changing patterns of 'green' total factor productivity (GTFP) growth of 38 Chinese industrial sectors during the period 1980–2010. Unlike the measures of traditional total factor productivity (TFP) growth, the DDF incorporates carbon dioxide emissions as an undesirable output directly into the production technology, which credit sectors for simultaneously reducing their emissions and increasing their output. The estimates of aggregate and sector-level GTFP growth reveal that Chinese industry is not yet on the path towards sustainable, low-carbon growth. A dynamic panel data analysis of the determinants of GTFP across sectors is used to identify factors that might rectify this situation, including state-owned enterprise reform, the growth of small private enterprises, continued openness to foreign investment and higher spending on R&D, particularly in emission-intensive sectors.

15/00429 Integrating multicriteria evaluation and stakeholders analysis for assessing hydropower projects

Rosso, M. *et al. Energy Policy*, 2014, 67, 870–881.

The use of hydroelectric potential and the protection of the river ecosystem are two contrasting aspects that arise in the management of the same resource, generating conflicts between different stakeholders. The purpose of the paper is to develop a multi-level decision-making tool, able to support energy planning, with specific reference to the construction of hydropower plants in mountain areas. Starting from a real-world problem concerning the basin of the Sesia Valley (Italy), an evaluation framework based on the combined use of multicriteria evaluation and stakeholders analysis is proposed in the study. The results of the work show that the methodology is able to grant participated decisions through a multi-stakeholders traceable and

transparent assessment process, to highlight the important elements of the decision problem and to support the definition of future design guidelines.

15/00430 Prioritization of renewable energy sources for Turkey by using a hybrid MCDM methodology

Kabak, M. and Dağdeviren, M. *Energy Conversion and Management*, 2014, 79, 25–33.

Developing countries such as Turkey, with their fast growing population and economy, are facing an increasing demand for energy. Turkey does not possess a sufficient quantity of domestic oil and natural gas resources to support this growing demand. On the other hand, the country does have abundant reserves of renewable energy that can be a major component in providing part of the overall energy supply. The country plans to explore its renewable energy (RE) sources and increase the renewable energy share in near future. With this in mind, this paper proposes a hybrid model based on benefits, opportunities, costs and risks (BOCR) and analytic network process (ANP) to determine Turkey's energy status and prioritize alternative RE sources. BOCR analysis provides a strategic analysis and detailed overview of the country's energy issues. ANP is a practical multi-criteria decision making method and offers the advantages of decision making models, based on tangible and intangible factors. Nineteen criteria are used to evaluate five alternative RE sources (hydro, geothermal, solar, wind and biomass). The subsequent results show that the most important strategic criterion is economy; other criteria include security, human wellbeing, technology and global effects. Their weights are 0.485, 0.235, 0.130, 0.097 and 0.053, respectively. In the conclusion of this paper, the authors propose hydro power as the optimal RE source for the Turkey.

15/00431 Risk implications of renewable support instruments: comparative analysis of feed-in tariffs and premiums using a mean-variance approach

Kitzing, L. *Energy*, 2014, 64, 495–505.

Different support instruments for renewable energy expose investors differently to market risks. This has implications on the attractiveness of investment. The authors use mean-variance portfolio analysis to identify the risk implications of two support instruments: feed-in tariffs and feed-in premiums. Using cash flow analysis, Monte Carlo simulations and mean-variance analysis, they quantify risk-return relationships for an exemplary offshore wind park in a simplified setting. The authors show that feed-in tariffs systematically require lower direct support levels than feed-in premiums while providing the same attractiveness for investment, because they expose investors to less market risk. These risk implications should be considered when designing policy schemes.

15/00432 Seawater pumped storage systems and offshore wind parks in islands with low onshore wind potential. A fundamental case study

Al. Katsaprakakis, D. and Christakis, D. G. *Energy*, 2014, 66, 470–486. This study investigates the effects of introducing a wind-powered pumped storage system (WP-PSS) in isolated electricity systems assuming unfavourable conditions such as low onshore wind potential and low PSS head height. These disadvantages can be compensated with the installation of offshore wind parks, larger reservoirs and double penstocks to allow simultaneous water fall and pumping using pipes of the greatest diameter that are currently commercially available. With the above modifications, the energy efficiency of the WP-PSS improves while the installation costs rise. A new operation algorithm for the WP-PSS is created to fully utilize the capacity of the double penstock and ultimately maximize wind energy penetration. A case study for a WP-PSS on the island of Rhodes is presented in this paper. Despite unfavourable conditions, the WP-PSS model illustrated that annual wind energy penetration exceeds 50% of the annual electricity consumption and WP-PSS exhibits attractive financial inducements without including any subsidies. The WP-PSS presented proved to be technically and economically feasible and revealed that WP-PSSs are a guaranteed choice for large-scale penetration of renewable energy sources in electrical systems.

15/00433 Separated magnet yoke for permanent magnet linear generator for marine wave energy converters

Gargov, N. P. et al. *Electric Power Systems Research*, 2014, 109, 63–70. In this paper the performance of a longitudinal flux permanent magnet linear generator (PMLG) for wave energy converters is investigated. The influence of the number of slots per pole, phase q and the number of stator's winding sections are analysed. The power output and the cogging forces in the PMLG are calculated and reviewed with respect to the above design parameters. In addition, an optimized PMLG model is designed and simulated. Three-dimensional finite element method (FEM) is used for solving the combined field and circuit equations of the generator. The simulated results show that the optimized model delivers a reduction in the X - and the Y -axes forces by

55% and 28%, respectively, and an increase of the output power by 233% in comparison with a model with a non-separated translator with the same volume of permanent magnet material.

15/00434 Short-term hydropower optimal scheduling considering the optimization of water time delay

Ge, X.-I. et al. *Electric Power Systems Research*, 2014, 110, 188–197.

This paper is proposed to develop a novel mixed-integer model to solve the short-term hydropower optimal scheduling problem. The model is designed with consideration of the optimization of water time delay. The water time delay is the time required for discharging water from upstream reservoir to its downstream reservoir. It is always in change, which makes a real challenge to handle the corresponding mathematical models. In order to develop the model, water time delay was formulated as a non-linear function of the outflow from upstream reservoir, which can describe the coupling of hydraulic and electric among cascaded hydropower stations accurately. Meanwhile, the complicated head-sensitive water-to-power conversion and piecewise output limits are also taken into account. To overcome the difficulty of solving the mixed-integer non-linear optimization problem, the formulation above is converted into a mixed integer linear programming (MILP) problem in terms of integer algebra techniques. The applied commercial software is called CPLEX, which can solve the related MILP problem successfully. Based on a case study with 13 reservoirs and 44 hydropower units, the study shows that the proposed model with water-time-delay can improve the operability and economic benefits of scheduling.

15/00435 The merit order effect of wind and photovoltaic electricity generation in Germany 2008–2016: estimation and distributional implications

Cludius, J. et al. *Energy Economics*, 2014, 44, 302–313.

Generation from renewable energy sources in Germany has experienced a considerable uptake in recent years. Mainly responsible for this development is the German Renewable Energy Sources Act (Erneuerbare Energien Gesetz, EEG). This paper considers redistributive implications of the EEG for different electricity consumers. Using time-series regression analysis, the authors show that electricity generation by wind and photovoltaics has reduced spot market prices considerably by €6/MWh in 2010 rising to €10/MWh in 2012. The authors use these results to build a near-term forecasting tool for merit order effects, projected to reach €14–16/MWh in 2016. On the other hand, the costs of the EEG are passed forward to consumers in the form of a surcharge. The findings highlight significant redistributive transfers under the current design of the EEG. In particular, some energy-intensive industries are benefiting from lower wholesale electricity prices whilst being largely exempted from contributing to the costs of the scheme. The authors also highlight the implications of the results for other areas for reform of the EEG, such as adequate remuneration mechanisms that ensure efficient operation and investment decisions are made under the scheme. More generally, these findings suggest that policy makers need to integrate distributional assessments into policy design and implementation.

15/00436 Tidal stream energy impacts on estuarine circulation

Ramos, V. et al. *Energy Conversion and Management*, 2014, 80, 137–149.

Among the impacts on the marine environment associated with the operation of a tidal farm, the alteration of the transient and residual flow velocities must be assessed in detail, for they constitute the driving force of important environmental processes such as sediment and pollutant transport, and nutrient dispersion. The objective of this study is to assess the impacts caused by the operation of a tidal farm on the transient and residual flow by means of a case study: a tidal stream farm in Ria de Ribadeo, an estuary in north-western Spain. For this purpose a three-dimensional numerical model of the estuary is implemented and successfully validated based on field data of tidal levels and flow velocities. The energy extracted by the tidal stream farm from the flow is accounted for by adding a momentum sink term in the equations of the model. Two scenarios representative of typical winter and summer conditions are considered. The results show that the disturbances to the transient flow patterns are concentrated in the proximity of the farm, with a weakening of the flow upstream and, especially, downstream of the farm (up to 0.25 m s^{-1}) and an intensification on both sides (up to 0.10 m s^{-1}). As for the residual flow, it was found that the operation of the tidal farm does not disrupt the complex three-dimensional residual circulation of the ria, but it does lead to modifications of the residual flow of up to 0.025 m s^{-1} , or approximately 10% of the baseline residual flow, which affect a much larger area than in the case of the transient flow (up to approximately 2 km from the farm). The repercussions of these alterations of the transient and residual flow patterns of the estuary for its sedimentary

and biological processes warrant further research. Overall, these results confirm the importance of assessing the impacts of a tidal stream farm on the flow.

15/00437 Transmission network expansion planning for the Colombian electrical system: connecting the Ituango hydroelectric power plant

Vinasco, G. *et al. Electric Power Systems Research*, 2014, 110, 94–103. The hydroelectric power plant HidroItuango represents a major expansion for the Colombian electrical system (with a total capacity of 2400 MW). This paper analyses the possible interconnections and investments involved in connecting HidroItuango, in order to strengthen the Colombian national transmission system. A mixed binary linear programming (MBLP) model was used to solve the multistage transmission network expansion planning (MTEP) problem of the Colombian electrical system, taking the $N-1$ safety criterion into account. The $N-1$ safety criterion indicates that the transmission system must be expanded so that the system will continue to operate properly if an outage in a system element (within a pre-defined set of contingencies) occurs. The use of a MBLP model guaranteed the convergence with existing classical optimization methods and the optimal solution for the MTEP using commercial solvers. Multiple scenarios for generation and demand were used to consider uncertainties within these parameters. The model was implemented using the algebraic modelling language AMPL and solved using the commercial solver CPLEX. The proposed model was then applied to the Colombian electrical system using the planning horizon of 2018–2025.

15/00438 Use of biodiesel in marine fuel formulation: a study of combustion quality

dos Santos Prucolo, E. *et al. Fuel Processing Technology*, 2014, 122, 91–97.

The quality of ignition and combustion of blends of soy biodiesel and marine fuels was evaluated. Faced with the increasing implementation of processes for converting heavier oil fractions, the availability of streams to formulate marine fuels has been reduced. In this context, the use of biodiesel is important to minimize problems caused by the retraction in production of these streams and improve marine fuel quality. Since composition and stability properties are of great importance and influence directly the combustion quality, the composition was determined using the SARA analysis by thin layer chromatography and a flame ionization detector and the mixtures' stability evaluation was made by optical scanning. Using the equipment fuel combustion analyser, mixtures of marine fuels and soy biodiesel were tested, varying the biodiesel content by volume in the mixture at levels up to 10% v/v. The results show that the addition of biofuel to marine fuels, in the evaluated conditions, does not compromise the combustion quality of the bunker oil and, in some cases, had even increased the estimated cetane number, indicating increased quality of ignition and combustion.

15/00439 Woody biomass energy potential in 2050

Lauri, P. *et al. Energy Policy*, 2014, 66, 19–31.

From a biophysical perspective, woody biomass resources are large enough to cover a substantial share of the world's primary energy consumption in 2050. However, these resources have alternative uses and their accessibility is limited, which tends to decrease their competitiveness with respect to other forms of energy. Hence, the key question of woody biomass use for energy is not the amount of resources, but rather their price. This study considers the question from the perspective of energy wood supply curves, which display the available amount of woody biomass for large-scale energy production at various hypothetical energy wood prices. These curves are estimated by the global biosphere management model, which is a global partial equilibrium model of forest and agricultural sectors. The global energy wood supply is estimated to be 0–23 Gm³/year (0–165 EJ/year) when energy wood prices vary in a range of \$0–30/GJ (\$0–216/m³). If household fuelwood is added to energy wood, then woody biomass could satisfy 2–18% of world primary energy consumption in 2050. If primary forests are excluded from wood supply then the potential decreases up to 25%.

14 FUEL SCIENCE AND TECHNOLOGY

Fundamental science, analysis, instrumentation

15/00440 A comparative trend in forecasting ability of artificial neural networks and regressive support vector machine methodologies for energy dissipation modeling of off-road vehicles

Taghavifar, H. and Mardani, A. *Energy*, 2014, 66, 569–576.

Machine dynamics and soil elastic-plastic characteristics describe the soil-wheel interaction as a very complex problem to be estimated. Energy dissipation due to motion resistance, as the most prominent performance index of towed wheels, is associated with soil properties and tyre parameters. The objective of this study was to develop, for the first time, a model for the prediction of the energy loss in soil-working machines using the datasets obtained from a soil bin facility and a single-wheel tester. A total of 90 data points were derived from experiments at five levels of wheel load (1, 2, 3, 4 and 5 kN), six tyre inflation pressure (50, 100, 150, 200, 250 and 300 kPa) and three forward velocities (0.7, 1.4 and 2 m/s). Artificial neural network (ANN) was used for the modelling of the obtained results compared to the forecasting ability of support vector regression (SVR) technique. Several statistical criteria (i.e. mean absolute percentage error, mean square error, mean relative error and coefficient of determination) were incorporated in the investigations. It was observed, on the basis of statistical criteria, that the SVR-based generalized model outperformed ANN in modelling the energy loss and exhibited its applicability as a promising tool in this domain.

15/00441 A modified artificial bee colony based on chaos theory for solving non-convex emission/economic dispatch

Shayeghi, H. and Ghasemi, A. *Energy Conversion and Management*, 2014, 79, 344–354.

In this paper, a modified artificial bee colony (ABC) based on chaos theory (CIABC) is comprehensively enhanced and effectively applied for solving a multi-objective emission/economic dispatch (EED) problem to minimize three conflicting objective functions with non-smooth and non-convex generator fuel cost characteristics while satisfying the operation constraints. The proposed method uses a chaotic local search (CLS) to enhance the self-searching ability of the original ABC algorithm for finding feasible optimal solutions of the EED problem. Also, many linear and non-linear constraints, such as generation limits, transmission line loss, security constraints and non-smooth cost functions are considered as dynamic operational constraints. Moreover, a method based on fuzzy set theory is employed to extract one of the Pareto-optimal solutions as the best compromise one. The proposed multi objective evolutionary method has been applied to the standard IEEE 30-bus six generators, 14 generators and 40 thermal generating units, respectively, as small, medium and large test power systems. The numerical results obtained with the proposed method based on tables and figures compared with other evolutionary algorithms in the scientific literature. The results regards that the proposed CIABC algorithm surpasses the other available methods in terms of computational efficiency and solution quality.

15/00442 A non-contact graphene surface scattering rate characterization method at microwave frequency by combining Raman spectroscopy and coaxial connectors measurement

Wei, X.-C. *et al. Carbon*, 2014, 77, 53–58.

A non-contact method is proposed to characterize graphene at microwave frequency by combining Raman spectroscopy and an Amphenol precision connector (APC-7). The chemical vapour deposition-grown graphene is transferred to the ring-shape Teflon substrate and characterized by Raman spectroscopy to estimate its doping density and the related Fermi energy. The graphene is then sandwiched between two APC-7 coaxial connectors and S parameters under transverse electromagnetic mode normal incident waves are measured to extract the surface conductivity through transmission matrix, in which the de-embedding process can be avoided. By combining the Kubo formula with the proposed circuit model, the scattering rate of graphene on Teflon substrate is obtained and analysed.

15/00443 A Rankine source computation for three dimensional wave-body interactions adopting a nonlinear body boundary condition

Feng, A. *et al. Applied Ocean Research*, 2014, 47, 313–321.

A three-dimensional wave-body interaction problem is numerically simulated by a Rankine source scheme in combination with a mixed Euler–Lagrange method. Singular free surface source points are placed exterior to the free surface, which is known as a desingularized method, and free surface boundary conditions are satisfied along control points on the computational domain. A new source distribution algorithm incorporating vertical desingularized distance and horizontal free surface source arrangements is developed and the method connects body panel size to free surface panel size. The non-linear or exact body boundary condition is captured by regriding the wetted body surface at each time step. A Lagrangian frame of reference is used to capture the motion of singularities during the regriding process. The non-linear effects caused by the variation of the wetted body surface are evaluated based on this method. The numerical scheme of study is shown to be computationally efficient and computation time is significantly reduced in comparison with earlier numerical investigations using the desingularized method.

15/00444 Assessment of the influence of shortening the duration of TRT (thermal response test) on the precision of measured values

Bujok, P. *et al. Energy*, 2014, 64, 120–129.

In this paper the results of testing thermal parameters of the rock environment and measurement of borehole temperature profiles of the newly constructed experimental underground heat storage, borehole thermal energy storage (BTES), in Paskov, Czech Republic, obtained with the thermal response method (TRT) and temperature measurement on boreholes at selected depth levels are summarized. The TRT measurement series on eight boreholes has shown the possibility to compare the differences among individual measurements in a practically identical rock environment. The temperature profiling of boreholes enabled studying the dynamics of temperature changes occurring in the rock environment as a reaction to the heat supply during the TRT. The measurement series was performed with the aim to assess the possibility of shortening the TRT duration while maintaining the acceptable precision of the measured results. For this reason the software simulation of shortening the TRT duration to 24 h was performed, and the influence of such shortening to the precision of determination of thermal conductivity and thermal resistance was studied. The simulation has shown that shortening the test to 24 h in this case would have brought an acceptable amount of inaccuracy with regard to the dispersion of measured values obtained from the real test.

15/00445 Comparison of flow instabilities under static condition and marine motion conditions based on experiments

Tang, Y. *et al. Annals of Nuclear Energy*, 2014, 70, 11–20.

An experimental investigation was performed on two-phase flow instability with twin parallel rectangular channels under static condition and marine motion conditions. Marine motion conditions include inclination, fluctuation and rolling. The maximum inclination angle is 45°, maximum amplitude and acceleration of fluctuation are 0.8 m and 1.9 m/s, respectively; maximum amplitude and angular acceleration of rolling are 30° and 0.5 rad/s², respectively. Test thermal parameters are 3–8 MPa for pressure, 300–700 kg/m²s for mass velocity, and 15–90 °C for inlet subcooling in this experiment. Comparisons have been made on four aspects: (1) general observation of flow oscillation; (2) period of flow oscillation; (3) flow instability boundary heat flux; (4) flow instability zone under static condition and motion conditions. Contrary to what is observed under static condition, the flow oscillation under motion conditions is actually the superposition of thermal-induced oscillation and motion-induced oscillation. But further comparison indicates that the influence of marine motion conditions on flow stability is very limited. In general, the period of oscillation, flow instability boundary heat flux and distribution of instability zone are much more affected by thermal parameters than the motion conditions and the point to point comparison shows that the differences of boundary heat flux brought by motion is no more than ±5%. Finally, an empirical formula considering a pressure correction is correlated based on experimental data, which is applicable for the prediction of the instability boundary under both static and motion conditions.

15/00446 Effect of the electrochemical oxidation/reduction cycle on the electrochemical capacitance of graphite oxide

Tateishi, H. *et al. Carbon*, 2014, 76, 40–45.

Reduction largely affects the properties of graphene oxide (GO), because the content of each functional group changes by the oxidation degree. So far no study about re-oxidation and re-reduction of GO has been carried out. This study reports the effects of oxidation/reduction cycle of graphite oxide (GtO, multilayered GO) on its composition and

electrochemical capacitance property. Electrochemical oxidation and reduction of glassy carbon (GC) were conducted at potentials of +2.0 and −1.1 V (vs Ag/AgCl), respectively, and then the electrochemical capacitances were measured. According to X-ray photoelectron spectroscopy analysis, C=C bonds were produced from CH defects of the reduced graphite oxide (rGtO) by the electrochemical re-oxidation. The conductivities of the reduced samples, with CH defects, and re-oxidized samples, with newly produced C=C bonds, were high and low, respectively. The high electrochemical capacitance observed for the rGtO electrodes is caused by the activity of the CH defects and good conduction.

15/00447 Energy tariffs in a small open economy

Thompson, H. *Energy Economics*, 2014, 44, 63–67.

Tariffs on imported energy alter production and redistribute income. The present paper examines a small open economy producing two traded goods with capital, labour and imported energy. A tariff reduces import and domestic factor income but payment to one domestic factor rises. Energy intensive output falls but the other output may rise in the general equilibrium. Political opinions on the tariff would differ. Revenue is concave in the tariff suggesting that the government might set the tariff to maximize revenue. A simulation illustrates these general equilibrium properties across a range of tariffs.

15/00448 Evaluation of multi-walled carbon nanotube concentrations in polymer nanocomposites by Raman spectroscopy

Bounos, G. *et al. Carbon*, 2014, 76, 301–309.

A new Raman spectroscopic methodology is proposed to monitor the weight fraction of multi-walled carbon nanotubes (MWCNTs) in polymeric nanocomposites. In order to disentangle the parameters affecting the frequency of the Raman bands and their intensity, this methodology involves the acquisition of sets of Raman spectra as a function of MWCNTs loading, excitation laser power and temperature. In the specific case of isotactic polypropylene (iPP), any interaction of the carbon nanotubes with the polymeric host has minimal effect on the frequency of the MWCNTs G-band (~1584 cm^{−1}); the same holds for the influence of residual stresses acting on the MWCNTs. The parameter that primarily alters the carbon nanotubes' Raman bands frequency is temperature, determined by the excitation laser intensity, the MWCNTs' concentration and the thermal properties of the polymer matrix. This is demonstrated by confocal micro-Raman spectra collected from agglomerates and from micro-Raman spectra of samples containing either poorly or well dispersed MWCNTs. A direct correlation of the G-band frequency with the effective MWCNT wt% loading in the nanocomposites is confirmed after careful and systematic experiments performed on prototype well-dispersed samples.

15/00449 Hydraulics of a multiple slit-type energy dissipater

Wu, J.-h. *et al. Journal of Hydrodynamics, Ser. B*, 2014, 26, (1), 86–93.

With the constructions of high dam projects in China, the energy dissipation downstream of a dam becomes a serious concern. In this study, a multiple slit-type energy dissipater, with different reduction size slits in the outlet, is developed on the basis of conventional slit-type energy dissipaters, aiming to enhance the energy dissipation through the turbulence and the friction between the different layers of the jet flow and the air entrainment due to the increased surface of the flow to the air. The hydraulic characteristics of the energy dissipater are experimentally investigated by means of three sets of physical models in nine cases, to characterize the geometric parameters with suitable performance. The main concerns are the flow regime, the jet flow trajectory, the energy dissipation, the cavitation characteristics, and the flow choking. The results indicate that the dissipater enjoys a high energy dissipation ratio with suitable hydraulic performance comparing with the conventional slit-type energy dissipaters.

15/00450 Improving the carbon balance of fermentations by total carbon analyses

Buchholz, J. *et al. Biochemical Engineering Journal*, 2014, 90, 162–169.

Carbon balancing of microbial fermentations is a valuable tool for the evaluation of the process performance and to identify the presence of undesired by-products. This study demonstrates the relevance of total carbon (TC) analysis for carbon balancing in fermentations with the wild-type of *Corynebacterium glutamicum* by (i) quantifying significant amounts of dissolved inorganic carbonic species (TIC) in the culture medium and (ii) determining the effective (mass) carbon content of the biomass fraction ($M_{C,X}$). In principle, TC-based carbon balancing yielded at fully matching carbon balances. Thus, the application of the TC approach for the accurate detection of TIC and $M_{C,X}$ increased the total carbon recovery in standard batch fermentations with *C. glutamicum* on glucose from about 76% to carbon closures of 94–100% in contrast to conventional approaches. Besides, the origin of the missing 6%-gap could be attributed to incomplete quantification of all

carbon sources in the liquid phase. To conclude this study, the concept of TC-based balancing was transferred to an L-lysine production process, successfully quantifying relevant system carbon fractions, which resulted in matched carbon recoveries.

15/00451 Mathematical model validation of a thermal architecture system connecting east/west radiators by flight data

Torres, A. *et al. Applied Thermal Engineering*, 2014, 66, (1–2), 1–14. A novel satellite thermal architecture connecting the east and west radiators of a geostationary telecommunication satellite via loop heat pipes (LHPs) is flight tested on board the satellite Hispasat 1E. The LHP operating temperature is regulated by using pressure regulating valves. The flight data demonstrated the successful operation of the proposed concept. A transient numerical model specifically developed for the design of this system satisfactorily simulated the flight data. The validated mathematical model can be used to design and analyse the thermal behaviour of more complex architectures.

15/00452 Maximum wave power absorption by slender bodies of arbitrary cross sections in oblique seas

Nihous, G. C. *Applied Ocean Research*, 2014, 47, 17–27. Published results for the maximum wave power absorption by slender bodies subjected to vertical deformations are extended. To this end, a more general form of the Kochin function is derived for floating or submerged slender bodies of arbitrary (asymmetric) cross-sections undergoing vertical or horizontal deformations. The Kochin function allows a determination of the theoretical maximum wave power absorption in oblique seas. It is shown that in beam seas, two-dimensional limits can be recovered when the slender body length tends to infinity. This establishes a formal continuity in behaviour from attenuators (head seas) to terminators (beam seas). The wavelike vertical and horizontal deformations of a flexible body, as well as the hinge motions of an articulated raft are also considered in oblique seas. In the former case, results suggest an equivalence between the maximum absorption width of bodies with symmetric cross-sections and two degrees of freedom, and that of bodies with optimal cross-sections and one degree of freedom. Overall, the potential for significant wave power absorption from horizontal motions is also demonstrated.

15/00453 Modeling space–time evolution of flux in a traveling wave reactor

Shrestha, R. and Rizwan-uddin, *Annals of Nuclear Energy*, 2014, 70, 90–95.

Simulations have been carried out using Monte Carlo code MCNPX to evaluate the space and time evolution of flux in a prototype travelling wave reactor under constant thermal power condition. A three-dimensional box-shaped model of the reactor is developed. The reactor core is divided into two primary regions: the smaller, enriched region with fissile material; and the larger non-enriched region with fertile material. This enrichment strategy is aimed to allow breed-and-burn in the core. The core, on the outside, is surrounded by shielding material of uniform thickness. To facilitate the study, these two primary regions in the core are further divided into thin slab-like regions referred to as cells. Results show propagation of flux profile from the enriched region to the non-enriched region at a near constant speed. Analyses of time evolution of local power density (power fraction) at specified locations in the core are presented. Space and time evolution of the overall core burn-up and localized burn-up are discussed.

15/00454 Modeling the energy consumption of a lift

Ahmed, S. S. *et al. Energy and Buildings*, 2014, 71, 61–67. A semi-rigorous and generalized model has been developed to determine the electrical energy (watt-hour) consumed by the motor of a typical lift in each step of an upward or a downward travel cycle. The model has been validated comparing its output with the actual readings taken from an energy meter (installed at the terminal of the motor) for several cycles of the traffic according to the existing route map for a real-life lift. The developed model can be used as a decision support tool by the energy managers of high rise buildings to revise the route map of a group of lifts time to time depending upon the needs. With the model they can simulate intended variations in the floor and traffic plans and compare their impacts upon the energy consumption. As an example the developed model has been demonstrated for the system of three lifts located in the 20-storey main building of BRAC University, Dhaka, Bangladesh.

15/00455 Moving beyond the limits of mass transport in liquid absorbent microfilms through the implementation of surface-induced vortices

Bigham, S. *et al. Energy*, 2014, 65, 621–630. The slow diffusion of an absorbate molecule into an absorbent often makes the absorption process a rate-limiting step in many applications. In cases involving an absorbate with a high heat of phase change, such

as water absorption into a LiBr (lithium bromide) solution, the absorption rate is further slowed due to significant heating of the absorbent. Recently, it has been demonstrated that constraining a LiBr solution film by a hydrophobic porous structure enables manipulation of the solution flow thermohydraulic characteristics. Here, it is shown that mass transport mode in a constrained laminar solution flow can be changed from diffusive to advective. This change in mode is accomplished through stretching and folding the laminar streamlines within the solution film via the implementation of micro-scale features on the flow channel surface. The process induces vortices within the solution film, which continuously bring concentrated solution from the bottom and middle of the solution channel to its interface with the vapour phase, thus leading to a significant enhancement in the absorption rate. The detailed physics of the involved transport processes is provided using the Lattice Boltzmann Method.

15/00456 Multicriteria analysis of agricultural raw materials: a case study of BSBIOS and Petrobras Biofuels in Brazil

José Zonin, V. *et al. Energy Policy*, 2014, 67, 255–263. Energy crises reverberate within societies and encourage worldwide change in this industry. In this context, Brazil has been consolidating the National Programme for the Production and Use of Biodiesel (Programa Nacional de Produção e Uso do Biodiesel – PNPB). This paper analyses BSBIOS and Petrobras Biofuels, which is a company that is incorporated under the PNPB. After providing an overview, the study focuses on the criteria used for the selection of the agricultural raw materials used in the biodiesel industry. A reference model that considered the economic, technological, and social dimensions was developed; these dimensions were analysed in relation to the production matrices of the soybean, canola, sunflower and castor plants. The company strategically opted to establish programmes for promoting the production of only soybean and canola. In the short term, the company has accepted the evidence that the main source of raw materials is soybean production. This decision was made considering the multicriteria analysis that was developed, which involved a number of economic, technological, and social aspects. Consequently, this analysis used in the decision-making process exhibits both a macro (the national and international environment) and a micro perspective (the companies' reality).

15/00457 Numerical analysis of force-feedback control in a circular tank

Gyongy, I. *et al. Applied Ocean Research*, 2014, 47, 329–343. The advent of circular wave tanks, with wave-making segments all around the perimeter, brings potential advantages over standard, rectangular wave tanks where the wave-maker is confined to one or two adjacent sides of the tank. It is now possible to reproduce seas with full 360° directionality, enhancing the range of possible test scenarios. However, this additional capability also presents technical challenges: waves generated on 'one side' of the tank must be absorbed on the opposite side, together with any waves reflected or radiated by the model under test, to prevent contamination of the wave field. This paper reviews the theory of wave generation and absorption in a circular tank, before proceeding to identify an appropriate control scheme for the University of Edinburgh's 'FloWave' combined wave/current basin. Numerical simulations, based on linear multi-chromatic waves, are carried out using WAMIT to assess the suitability of wave-maker control schemes suggested in literature. For the first time a round tank's ability to reproduce sea spectra is assessed numerically. The simulations suggest that the generation of 'peaked' spectra is possible to an accurate degree, with an overall standard deviation error of less than 2% over a designated 'test zone'. However, there are difficulties in producing 'wide' spectra, as effective dynamic wave absorption cannot be ensured over the whole frequency range. This may have important repercussions, not just for the usage of FloWave, but also in terms of the design of future round basins.

15/00458 Numerical modelling of thermal regimes in steel energy pile foundations: a case study

Gashti, E. H. N. *et al. Energy and Buildings*, 2014, 69, 165–174. Heating/cooling operations of ground heat exchangers (GHEs) incorporated with steel pile foundations were simulated in a three-dimensional numerical model using the Comsol Multiphysics program. Acceptable agreement between numerical and experimental results denoted high ability of the finite element method used in the model to predict system operation. Use of the model to compare the performance of several GHEs in terms of their efficiency revealed that double U-tube systems have greater productivity than single U-tube systems at a particular fluid flow rate. The model was further used to analyse thermal regimes generated in pile shaft in different heating/cooling modes, in which two zones with different thermal profiles (steady state and transient) were identified over the pile length, with the transient zone dominating. The final stabilized temperature in the pile shaft was found to be around 25–33% different to the inlet fluid

temperature. The results showed that the constant temperature assumption over the pile length used in some literature is not very realistic and can prevent correct prediction of mechanical behaviour in energy piles, in particular in the vicinity of the U-curve of polyethylene tubes at the end of piles.

15/00459 Optimization of automation: I. Estimation method of cognitive automation rates reflecting the effects of automation on human operators in nuclear power plants

Lee, S. M. *et al. Annals of Nuclear Energy*, 2014, 70, 48–55.

Since automation was introduced in various industrial fields, the concept of the automation rate has been used to indicate the inclusion proportion of automation among all work processes or facilities. Expressions of the inclusion proportion of automation are predictable, as is the ability to express the degree of the enhancement of human performance. However, many researchers have found that a high automation rate does not guarantee high performance. Therefore, to reflect the effects of automation on human performance, this paper proposes a new estimation method of the automation rate that considers the effects of automation on human operators in nuclear power plants (NPPs). Automation in NPPs can be divided into two types: system automation and cognitive automation. Some general descriptions and characteristics of each type of automation are provided, and the advantages of automation are investigated. The advantages of each type of automation are used as measures of the estimation method of the automation rate. One advantage was found to be a reduction in the number of tasks, and another was a reduction in human cognitive task loads. The system and the cognitive automation rate were proposed as quantitative measures by taking advantage of the aforementioned benefits. To quantify the required human cognitive task loads and thus suggest the cognitive automation rate, Conant's information-theory-based model was applied. The validity of the suggested method, especially as regards the cognitive automation rate, was proven by conducting experiments. The result showed that a decreased rate of the operator working time was significantly related to the cognitive automation rate and that the calculation of the cognitive task load was useful as a measure of the cognitive automation rate.

15/00460 Photoluminescence of nanoporous carbons: opening a new application route for old materials

Bandos, T. J. *et al. Carbon*, 2014, 77, 651–659.

Photoluminescence of oxygen, sulfur, and nitrogen containing nanoporous carbons was detected in the visible range. This behaviour was linked to the presence of sulfones, sulfoxides, sulfonic acids and nitrogen moiety, which act as chromophores in the carbon pore system. They absorb radiation close to visible range and electrons are transferred to the graphitic domains of carbon matrices, which are in the vicinity of these groups. This process results in photoluminescence, which was observed in spite of the strong light absorbing nature of carbons. These features of nanoporous carbons can open the new route for their applications as sensors and drug delivery carries.

15/00461 Quasi-static analysis of lightning-radiated electric field in the vicinity of sea-land structure

Zareian-Jahromi, E. *et al. Electric Power Systems Research*, 2014, 109, 112–117.

A quasi-static approach is presented to compute electric field radiated by a lightning return stroke above the sea-land structure modelled as a dielectric half space with a perfectly conducting half plane situated in its interface. It appears that the quasi-static approach provides a closed-form time-domain solution for the radiated electric field. The proposed approach is mainly based on the electrostatic solution of the structure. The governing Poisson's equation in the presence of the sea-land structure is solved in three dimensions, using the contributions of dielectric half space and perfectly conducting half plane. The solution, expressed in terms of image contributions, consists of two point images in physical space. The validity domain of the time-domain quasi-static approach is investigated by comparison of the obtained electric fields with full-wave results obtained using the finite-difference time-domain method. The proposed approach has a reasonable accuracy at near (200 m) distance range from the lightning channel.

15/00462 Research on characteristics of varying conditions for nozzle governing stage based on dimensional analysis

Xu, J.-q. *et al. Energy*, 2014, 65, 590–595.

In this paper, thermodynamic calculations of nozzle governing stage are taken based on advanced process simulation (APROS), and verify through the comparison of experiment table data. The influence of partial admission on the pressure ratio within the governing stage is also analysed. The results show that partial admission not only leads to partial admission losses, but also makes an impact on the pressure ratio, enthalpy and reaction degree, in turn, which causes the change of efficiency. The nozzle pressure ratio after the full-open valve and semi-open valve, respectively, is expressed as a function of flow ratio based on dimensional analysis. This paper presents a method of thermodyn-

amic calculation for the nozzle governing stage. Comparing with the results calculated through APROS and discussing the change of pressure ratio and reaction degree, it shows that the method can reflect the influence of partial admission on pressure ratio exactly, and further improve the accuracy of existing thermodynamic calculation.

15/00463 Sloshing in a rectangular tank based on SPH simulation

Cao, X. Y. *et al. Applied Ocean Research*, 2014, 47, 241–254.

A ship would generate significant sloshing when subjected to under-water explosion loads; the sloshing will reduce the ship's stability and even cause the ship to capsize when coupled with internal liquid sloshing. It is of great significance to research on the characteristics of the sloshing loads in a tank to improve the ship's stability and security. The liquid sloshing in a tank is a complex process characterized with non-linearity and strong randomness, and large amplitude sloshing is a great challenge for both theoretical models and numerical algorithms. Yet as a mesh-free method, smoothed particle hydrodynamics (SPH) has great advantages of solving such large deformation problems because of the nature of self-adaptiveness and Lagrangian. This paper focuses on the SPH core issues, such as the accuracy and the stability of the kernel function and boundary treatments. First, the accuracy and computational stability of four common SPH kernel functions are simply investigated by two simple cases, and a more appropriate kernel function is selected. Second, the dummy particles and a novel boundary treatment considering the boundary motion are applied. Furthermore, the laws of impact pressure of the two-dimensional tank under forced rolling with different excitation frequencies and excitation angles are studied. Then, the influences of a baffle for the liquid sloshing in a two-dimensional tank under forced surging are analysed, and the action mechanisms of the baffle are summarized. Finally, the coupled motion of swaying and surging for a three-dimensional tank is studied, which aims to lay a foundation for further study on the influence of sloshing loads on real ship motions.

15/00464 Spatial variability of waves within a marine energy site using in-situ measurements and a high resolution spectral wave model

Ashton, I. *et al. Energy*, 2014, 66, 699–710.

A high-resolution spectral wave model is used to quantify the spatial wave climate on geographical scales relevant to intra-site variability for marine renewable energy installations. For the first time, results are compared to *in situ* data from an array of four floating wave buoys, and demonstrate the ability of the spectral wave model SWAN (Simulating WAVes Nearshore) to resolve spatial differences in the wave climate. Examination of the model source terms highlights bottom friction and refraction as the primary processes contributing to the observed differences across the site. Wave models for climate assessments for marine renewable energy are not commonly operated at sufficient spatial resolution to accurately resolve intra-site variability. This study demonstrates that high spatial resolution spectral wave models, nested into a larger model domain, have the potential to provide an accurate and detailed prediction of the spatial variability of wave conditions across a marine renewable energy site. As such, they could be implemented to provide a more accurate resource assessment for wave energy array deployments, but also for engineering assessments of other marine energy technologies.

15/00465 Wave-thermocapillary effects in heated liquid films at high Reynolds numbers

Chinnov, E. A. *International Journal of Heat and Mass Transfer*, 2014, 71, 106–116.

The temperature distributions and wave characteristics of the water film flowing down a vertical plate with a heater of $100 \times 150 \text{ mm}^2$ at $Re = 150, 300$ and 500 are studied. The field of film thicknesses at different heat flux values was measured using the fluorescence method. The temperature field on the film surface was measured by an infrared scanner. The experimental data were obtained for variations in temperature over the liquid film surface with time during the propagation of waves. Thermocapillary forces that arise on heating lead to the formation of rivulets separated by thin layer troughs, with three-dimensional (3D) waves propagating over the crests of rivulets. Averaging of measurements allowed the values of the transverse film deformation and distance between the rivulets to be determined. In the inter-rivulet zone Marangoni number increases with a rise of the heat flux. The amplitudes of 3D waves in a water film flowing down a vertical heated plate have been measured. The film thickness and 3D wave amplitudes on the heater grow with increasing heat flux and distance downstream the flow, but the relative wave amplitude remains unchanged. In the heated regions between rivulets, the relative amplitude of waves increases with decreasing average thickness (or local Reynolds number). Analysis of results obtained for large Reynolds numbers showed that the relative amplitudes of waves in the regions between rivulets at high heat fluxes are much greater than those for small Reynolds numbers and in isothermal falling films. Two

mechanisms of thermocapillary forces influence on the motion of the wavy liquid film are marked. For the first time, the exhibition of such a strong thermocapillary effects is revealed in the heated liquid film at high Reynolds numbers.

Fuel cell technology

15/00466 A horizontal plug flow and stackable pilot microbial fuel cell for municipal wastewater treatment

Feng, Y. *et al. Bioresource Technology*, 2014, 156, 132–138.
An application-oriented stackable horizontal microbial fuel cell (SHMFC) was designed and proved to be capable for sewage treatment and simultaneously energy recovery. The system consisted of multiple stackable 250 L modules, which is the largest single microbial fuel cell (MFC) module by far. Domestic wastewater was fed into SHMFC in horizontal advection. During the stable operation period, a maximum current 0.435 ± 0.010 A in each module was observed under the external resistance of 1Ω and the maximum power density was 116 mW. The effluent chemical oxygen demand was 70 ± 17 mg L⁻¹ with a removal rate of $79 \pm 7\%$ and the effluent total nitrogen was 13 ± 3 mg L⁻¹ with a removal rate of $71 \pm 8\%$. From the comparison between SHMFC module (250 L) and 4-cm cubic MFC (28 mL), the internal resistance distribution changes and the contact resistance becomes assignable and even limiting factor in the enlargement.

15/00467 Analysis of operational characteristics of polymer electrolyte fuel cell with expanded graphite flow-field plates via electrochemical impedance investigation

Park, T. *et al. Energy*, 2014, 66, 77–81.
Expanded graphite was investigated as a material for flow-field plates in polymer electrolyte fuel cells (PEFCs). Because expanded graphite is flexible but has similar material properties with normal graphite, channels on flow-field plates were designed to have single channel in order to compare operational characteristics including diffusion of reactants through ribs by comparing polarization curves and electrochemical impedance spectra between PEFCs with expanded graphite and graphite flow-field plates. As a result, PEFC with the expanded graphite flow-field plates has comparable open-circuit voltage to that with the graphite flow-field plates. However, PEFC with the expanded graphite plates had higher ohmic resistance than that with the graphite plates due to higher electrical resistance of the expanded graphite than that of the graphite. It was also found from faradaic resistances that the diffusion of the reactants through gas diffusion layers (GDLs) is disturbed in the case of the expanded graphite flow-field plates because the GDL is compressed excessively due to its flexibility.

15/00468 Anodic microbial community diversity as a predictor of the power output of microbial fuel cells

Stratford, J. P. *et al. Bioresource Technology*, 2014, 156, 84–91.
The relationship between the diversity of mixed-species microbial consortia and their electrogenic potential in the anodes of microbial fuel cells was examined using different diversity measures as predictors. Identical microbial fuel cells were sampled at multiple time-points. Biofilm and suspension communities were analysed by denaturing gradient gel electrophoresis to calculate the number and relative abundance of species. Shannon and Simpson indices and richness were examined for association with power using bivariate and multiple linear regression, with biofilm DNA as an additional variable. In simple bivariate regressions, the correlation of Shannon diversity of the biofilm and power is stronger ($r = 0.65$, $p = 0.001$) than between power and richness ($r = 0.39$, $p = 0.076$), or between power and the Simpson index ($r = 0.5$, $p = 0.018$). Using Shannon diversity and biofilm DNA as predictors of power, a regression model can be constructed ($r = 0.73$, $p < 0.001$). Ecological parameters such as the Shannon index are predictive of the electrogenic potential of microbial communities.

15/00469 Application of solid oxide fuel cell for flare gas recovery as a new approach; a case study for Asalouyeh gas processing plant, Iran

Saidi, M. *et al. Journal of Natural Gas Science and Engineering*, 2014, 17, 13–25.
Flare gas emission is one of the main sources of environmental pollution and global warming. Implementations of some no flaring methods have a great impact in reducing the pollutants emission. Using solid oxide fuel cell (SOFC) system is a new approach which is proposed in this study. In this work, an electrochemical model is developed for a steady-state, planar SOFC by considering the direct internal methane steam reforming. In this new configuration, there is no pre-reforming and the sweetened flare gas is fed to SOFC directly. Also a part of required steam is supplied by recycling the anode outlet gas. The present model is validated with experimental and modelling

data taken from the literature. Application of SOFC technology for flare gas recovery of Asalouyeh gas processing plant not only generates about 1200 MW electrical energy, but also it decreases the equivalent mass of greenhouse gas emission from 1700 to 68 kg/s. Economical evaluations show that the total capital investment of this method is significantly lower than other no gas flaring approaches. For parametric investigation, the effects of some related parameters such as temperature, recirculation, fuel utilization and air ratios are studied. The results show that increasing the operating temperature of SOFC enhances the cell voltage and maximum power density. Decreasing the recirculation ratio from 0.6 to 0.2 increases the electrical efficiency of the cell. Although at lower current densities, changing the recirculation ratio has no significant effect, it is observed that at average current density equals to 1.5 A/cm², increasing the recirculation ratio from 0.2 to 0.6 decreases the power density from 0.51 W/cm² to 0.48 W/cm². Also increasing the fuel utilization ratio improves the cell performance.

15/00470 Characteristics of electricity generation and biodegradation in tidal river sludge-used microbial fuel cells

Touch, N. *et al. Bioresource Technology*, 2014, 158, 225–230.
The electricity generation behaviour of a microbial fuel cell (MFC) using sludge collected from the riverbank of a tidal river, and the biodegradation of the sludge by the electricity generation are evaluated. Although the maximum current density ($150\text{--}300$ mA/m²) was higher than that of MFC using freshwater sediment (30 mA/m²), the output current was greatly restricted by the mass transfer limitation. However, the results also indicate that placing the anode in different locations in the sludge could reduce the mass transfer limitation. After approximately 3 months, the removal efficiency of organic carbon was approximately 10%, demonstrated that MFC could also enhance the biodegradation of the sludge by nearly 10-fold comparing with the natural biodegradation. It was also found that the biodegradation could be identified by the behaviour of oxygen consumption of the sludge. Importantly, the oxygen consumption of the sludge became higher along with the electricity generation.

15/00471 Degradation modeling and operational optimization for improving the lifetime of high-temperature PEM (proton exchange membrane) fuel cells

Kim, J. *et al. Energy*, 2014, 66, 41–49.
High-temperature proton exchange membrane fuel cells (PEMFCs) using phosphoric acid-doped polybenzimidazole membranes have received attention as a potential solution to several of the issues with traditional low-temperature PEMFCs. However, the durability of high-temperature PEMFCs deteriorates rapidly with increasing temperature, although its performance improves. This characteristic makes it difficult to select the proper operating temperature to achieve its target lifetime. To resolve this problem, models were developed to predict the performance and durability of the high-temperature PEMFC as a function of operating temperature. The optimal operating temperature was then determined for a variety of lifetimes. Theoretical model to estimate cell performance and empirical model to predict the degradation rate of cell performance were constructed, respectively. The prediction results of the developed models agreed well with the experimental data. From the simulation, higher average cell performances were obtained by optimizing the operating temperature for the given target lifetime compared to the cell performance at some temperatures determined using an existing rule of thumb. It is expected that the proposed methodologies will lead to the more rapid commercialization of this technology in such applications as stationary and automotive fuel cell systems.

15/00472 Design and optimization of a proton exchange membrane fuel cell CHP system for residential use

Gandiglio, M. *et al. Energy and Buildings*, 2014, 69, 381–393.
This work deals with the analysis of a micro-cogeneration system for residential use based on a 1 kWe proton exchange membrane (PEM) fuel cell. A detailed system analysis of the fuel cell stack operating at an average temperature of 62 °C and the surrounding balance-of-plant are taken into account. The gas processing section and the heat recovery system were also designed and optimized in term of heat recovery. Low-grade waste heat, mainly recovered from the PEM stack and the burner exhaust, has been found suitable for feeding a low-temperature thermal user such a radiant floor heating system (operating at ~35–45 °C). According to this configuration, the heat-exchanger network has been optimized following the pinch analysis methodology, and the floor heating system has been sized accordingly. The micro-cogeneration system has been modelled in term of mass and energy balances while efficiency maps were obtained for a varying fuel utilization and current density of the stack. The maximum electrical efficiency achieved is around 36% (AC, LHV), with a stack current of 30 A and a fuel utilization of 80%. The global efficiency (that includes also heat recovery toward the thermal utility) is above 75% for same stack operating conditions. From the floor heating system sizing, the considered micro-combined heat and power (CHP) PEM system is

able to supply around 22.4% of the heat demand by a 50 m² medium-low efficiency building (class E – European Union classification) during the winter season. Nevertheless, taking into account a high-efficiency building (class A++), the heat released by the PEM plant can supply the overall required thermal load without requiring an auxiliary boiler.

15/00473 Electricity generation and microalgae cultivation in microbial fuel cell using microalgae-enriched anode and bio-cathode

Cui, Y. *et al. Energy Conversion and Management*, 2014, 79, 674–680. In this study, a microbial fuel cell (MFC) was developed to treat waste, produce electricity and to grow microalgae simultaneously. Dead microalgae biomass (a potential pollution vector in streams) was used as a substrate at anode. CO₂ generated at the anode was used to grow freshwater microalgae at the cathode. The performance of a microalgae-fed MFC was compared to an acetate-fed MFC. The maximum power density of $1926 \pm 21.4 \text{ mW/m}^2$ ($8.67 \pm 0.10 \text{ W/m}^3$, at $R_{\text{ext}} = 100 \Omega$) and Coulombic efficiency of $6.3 \pm 0.2\%$ were obtained at 2500 mg COD/L of microalgae powder (0.5 g/L). The microalgae captured CO₂ (5–14%, v/v) to produce a biomass concentration of $1247 \pm 52 \text{ mg/L}$. However, microalgae could not grow in an acetate-fed (0.5 g/L) MFC (acetate-control) and without anodic CO₂ supplying the MFC (CO₂-control).

15/00474 Energy and exergy analysis of an ethanol reforming process for solid oxide fuel cell applications

Tippawan, P. and Arpornwicheanop, A. *Bioresource Technology*, 2014, 157, 231–239.

The fuel processor in which hydrogen is produced from fuels is an important unit in a fuel cell system. The aim of this study is to apply a thermodynamic concept to identify a suitable reforming process for an ethanol-fuelled solid oxide fuel cell (SOFC). Three different reforming technologies, i.e. steam reforming, partial oxidation and autothermal reforming, are considered. The first and second laws of thermodynamics are employed to determine an energy demand and to describe how efficiently the energy is supplied to the reforming process. Effect of key operating parameters on the distribution of reforming products, such as H₂, CO, CO₂ and CH₄, and the possibility of carbon formation in different ethanol reformings are examined as a function of steam-to-ethanol ratio, oxygen-to-ethanol ratio and temperatures at atmospheric pressure. Energy and exergy analysis are performed to identify the best ethanol reforming process for SOFC applications.

15/00475 Evaluation and enhanced operational performance of microbial fuel cells under alternating anodic open circuit and closed circuit modes with different substrates

Sevda, S. *et al. Biochemical Engineering Journal*, 2014, 90, 294–300. The present study evaluates the performance of air-cathode microbial fuel cells (MFCs) under alternating open circuit/closed circuit (OC/CC) modes and its effect on independent-electrode and full-cell potentials, power output (at different external resistances) and the polarization behaviour of the electrodes. Three different types of feeds were evaluated using this approach: (1) phosphorus buffer solution (PBS) with acetate as carbon source, (2) glucose-rich synthetic wastewater, and (3) sewage from wastewater treatment plant enriched with fermented molasses. When MFCs were suddenly switched to CC from OC and then again back to OC from CC, the behaviour of the anodes vs reference electrode (Ag/AgCl, 3 M KCl) was monitored. When electric circuit of the MFCs was switched from open to closed circuit, for all cases: (a) the anode potential-shift (vs Ag/AgCl) reallocated in the positive direction in about 200–400 mV, (b) the air-cathode potential-shift (vs Ag/AgCl) reallocated in the negative direction in about 10–25 mV, and (c) the cell-potential difference started at around 0 mV and progressively increased as the MFC reached stability. This behaviour was consistently reproduced during different OC/CC cycles. The systems studied delivered good performance with both controlled media and industrial wastewater. Additionally, this study provides insightful characterization of the independent-electrode behaviours.

15/00476 Genuine design of compact natural gas fuel processor for 1-kW_e class residential proton exchange membrane fuel cell systems

Jung, U. H. *et al. Fuel Processing Technology*, 2014, 121, 32–37. A newly designed compact natural gas fuel processor, namely KIER prototype III, for 1-kW_e class residential proton exchange membrane (PEM) fuel cell systems has been developed. The system satisfies the main prerequisites for viable application such as 80% thermal efficiency on the basis of lower heating value at full load as well as CO concentration at PrOx exit less than 10 ppm on a dry basis by integrating internal heat exchange network between heat sources, e.g. burner flame, flue gas and reformed gas from reformer exit, and sinks, e.g. water, feed gas and air. The total system volume including

insulation is 13.5 L and also the response time at full load appeared to be less than 50 min. This work mainly describes the design strategies and the effects of independent parameters, e.g. steam methane reforming exit temperature and turn-down ratio, upon the response changes (carbon conversion and thermal efficiency). To develop an effective heat exchange network of a fuel processor, a commercial process simulation software package, Aspen Plus, has been used. Based on the simulation results of the conceptual design, a coaxial tubular fuel processor has been developed. Besides, the excellence of the thermally integrated system of the developed fuel processor is verified by comparing its actual operation data with the simulation results.

15/00477 Highly durable electrocatalyst with graphitized carbon supports modified by diazonium reaction for polymer electrolyte membrane fuel cell

Kim, J. Y. *et al. Carbon*, 2014, 77, 525–537.

This study presents the fabrication of highly durable catalyst with the graphitized carbon (GC) via diazonium chemistry for polymer electrolyte membrane fuel cell (PEMFC). The functionalization of the GC with the trifluoromethylphenyl groups by diazonium reaction was shown to enhance the distribution of Pt nanoparticles deposited on the functionalized GC surfaces and reduce their agglomeration, resulting in higher stability of Pt catalysts with enhanced activity as compared to the Pt/unmodified GC and a commercial Pt/C catalyst. The durability of the Pt/functionalized GC depends on the uniform distribution of Pt nanoparticles and the surface-grafted layers on the GC surfaces. The enhanced durability of the Pt/functionalized GC results from the combined effect of the *in situ* grafted layers acting as effective barriers for the migration of Pt nanoparticles and subsequent their agglomeration on the GC surfaces and the slow-down of the kinetics of the carbon oxidation reaction induced by high degree of graphitization. This study suggests that a facile functionalization through simple diazonium reaction in an effective way to fabricate highly durable Pt catalysts with enhanced activity for PEMFC, providing a design guide of functionalized carbon supports with a great potential as a PEMFC catalyst.

15/00478 Model based design and optimization of a fuel cell electric vehicle

Cipollone, R. *et al. Energy Procedia*, 2014, 45, 71–80.

Alternative vehicle powertrains (hybrid, hydrogen, electric) are a right answer to the emissions problem in very congested urban areas. The most effective alternative choice is surely represented by fuel cell vehicles. The design and optimization of this kind of powertrain can take a great benefit from mathematical models which include auxiliary management and control strategies of the energy fluxes: the use of a virtual platform limits the expensive and time-consuming experimental activity. The authors present a lumped parameter mathematical model of a hybrid vehicle fed by a fuel cell pack. The propulsion system (fuel cell and battery) is accurately designed according to energy balancing. The mechanical power is given by an electric machine, whose behaviour as alternator allows the energy recovery during braking. This aspect is treated with particular care (inside the overall vehicle and powertrain modelling). The vehicle's stability and safety has been also verified before recovering energy, re-modulating the braking action.

15/00479 Oxygen transport resistance correlated to liquid water saturation in the gas diffusion layer of PEM fuel cells

Owejan, J. P. *et al. International Journal of Heat and Mass Transfer*, 2014, 71, 585–592.

Under typical proton exchange membrane fuel cell (PEMFC) operating conditions, temperature gradients through the porous gas diffusion layer (GDL) can result in product water condensation. As a result, non-uniform partial saturation of the GDL changes the local effective porosity and tortuosity encountered by oxygen diffusing to the catalyst layer. This additional transport resistance reduces the partial pressure of oxygen at the catalyst surface of an air-fed cathode. In the current work, this phenomenon is investigated in two-dimensions using limiting current experiments that define GDL boundary conditions along with simultaneous neutron imaging to measure the local water content relative to the flow field geometry. The subsequent effective diffusion coefficient vs. saturation relationship derived from this method is reported for two common GDL carbon fibre substrates. It is also shown that the land vs channel distribution of liquid water must be accounted for to accurately predict diffusion resistance. These results represent the first time that the effect of water saturation on effective diffusion coefficient has been directly measured *in situ*, thus enabling accurate determination of the exponent 'n' in the modified Bruggeman relationship for two commercially available gas diffusion layer materials.

15/00480 Semiconducting amorphous carbon thin films for transparent conducting electrodes

Ur Rehman Sagar, R. *et al. Carbon*, 2014, 76, 64–70.

Semiconducting amorphous carbon thin films were directly grown on SiO₂ substrate by using chemical vapour deposition. Raman spectra and transmission electron microscopy image showed that the a-C films have a short-range ordered amorphous structure. The electrical and optical properties of the a-C thin films were investigated. The films have sheet resistance of 3.7 kΩ/□ and high transmittance of 82%. They exhibit metal-oxide-semiconductor field effect transistor mobility of 10–12 cm² V⁻¹ s⁻¹ at room temperature, which is comparable to previous reported mobility of amorphous carbon. The optical band gap was calculated by Tauc's relationship and photoluminescence spectra showed that the films are semiconductor with an optical band gap of 1.8 eV. These good physical properties make the a-C films a candidate for the application of transparent conducting electrodes.

15 ENVIRONMENT

Pollution, health protection, applications

15/00481 A method for the identification and modelling of realistic domestic occupancy sequences for building energy demand simulations and peer comparison

Aerts, D. *et al. Building and Environment*, 2014, 75, 67–78.

User behaviour plays a key role in the energy demand of residential buildings, and its importance will only increase when moving towards nearly zero-energy homes. However, little detailed information is available on how users interact with their homes. Due to the lack of information, user behaviour is often included in building performance simulations through one standard user pattern. To obtain more accurate energy demand simulations, user patterns are needed that capture the wide variations in behaviour without making simulations overly complicated. To this end, a probabilistic model was developed that generates realistic occupancy sequences that include three possible states: (1) at home and awake, (2) sleeping or (3) absent. This paper reports on the methodology used to construct this occupancy model based on the 2005 Belgian time-use survey. Using hierarchical clustering, seven typical occupancy patterns were identified. The modelling of individual occupancy sequences based on this method enables highly differentiated yet realistic behaviour to be included that is relevant to building simulations and can be used for individualized feedback based on peer comparison.

15/00482 A multilevel regression approach to understand effects of environment indicators and household features on residential energy consumption

Tso, G. K. F. and Guan, G. *Energy*, 2014, 66, 722–731.

Modelling residential energy consumption survey (RECS) data is a complex socio-technical problem that involves macroeconomics, climate, physical characteristics of housing, household demographics and usage of appliances. A multilevel regression (MR) model is introduced to calculate the magnitude and significance of effects of environment indicators and household features on residential energy consumption (REC). MR helps construct a conceptual framework and organize explanatory variables. The benefit of this approach is that based on stratified sampling schemes, MR extracts area effects from total variations of REC and explains the remaining variations with manifest variables and their interactions. Using the US 2009 RECS micro data consisting of 10,838 unique cases, 26 primary determinants of REC are found to be division groups, housing type, house size, usage of space heating equipment, household size and use of air-conditioning, etc. MR helps to quantify 82% of area effects and 47% of household effects. Proportion of the overall explained variance proportion is 53% compared to <40% using ordinary least squares regression models.

15/00483 Accounting for uncertainty in willingness to pay for environmental benefits

Daziano, R. A. and Achtnicht, M. *Energy Economics*, 2014, 44, 166–177.

Previous literature on the distribution of willingness to pay has focused on its heterogeneity distribution without addressing exact interval estimation. This study derives and analyses Bayesian confidence sets for quantifying uncertainty in the determination of willingness to pay for carbon dioxide abatement. Two empirical case studies were: household decisions of energy-efficient heating versus insulation, and purchase decisions of ultra-low-emission vehicles. The authors first

show that deriving credible sets using the posterior distribution of the willingness to pay is straightforward in the case of deterministic consumer heterogeneity. However, when using individual estimates, which is the case for the random parameters of the mixed logit model, it is complex to define the distribution of interest for the interval estimation problem. This latter problem is actually more involved than determining the moments of the heterogeneity distribution of the willingness to pay using frequentist econometrics. A proposed solution is to derive and then summarize the distribution of point estimates of the individual willingness to pay under different loss functions.

15/00484 Achieving carbon emission reduction through industrial & urban symbiosis: a case of Kawasaki

Dong, H. *et al. Energy*, 2014, 64, 277–286.

Industry and fossil fuel combustion are the main sources for urban carbon emissions. Most studies focus on energy consumption emission reduction and energy efficiency improvement. Material saving is also important for carbon emission reduction from a lifecycle perspective. Industrial symbiosis (IS) and urban symbiosis (U,S) have been effective since both of them encourage by-product exchange. However, quantitative carbon emission reduction evaluation on applying them is still lacking. Consequently, the purpose of this paper is to fill such a gap through a case study in Kawasaki Eco-town, Japan. A hybrid life cycle analysis model was employed to evaluate to the lifecycle carbon footprint. The results show that lifecycle carbon footprints with and without IS and U,S were 26.66 and 30.92 Mt CO₂e, respectively. The carbon emission efficiency was improved by 13.77% with the implementation of IS and U,S. The carbon emission reduction was mainly from the iron and steel, cement and paper-making industries with figures of 2.76, 1.16 and 0.34 Mt CO₂e, respectively. Reuse of scrap steel, blast furnace slag and waste paper are all effective measures for promoting carbon emission reductions. Finally, policy implications on how to further promote IS and U,S are presented.

15/00485 Agent-based simulations of the influence of social policy and neighboring communication on the adoption of grid-connected photovoltaics

Murakami, T. *Energy Conversion and Management*, 2014, 80, 158–164.

Agent-based simulations coupled with an analysis of the flow of electric power are carried out to examine the influence of the social policy of the government and the neighbouring communication between customers on the adoption of distributed rooftop photovoltaic electrical power generators (PVs). How the relationships between the social policy and the possibility of a reverse current restriction give rise to the collective behaviour of autonomous individuals, and how the end customers interact and form relationships with its environment are described. Strong intervention by the government in the areas near a main high-voltage power distribution transformer, where the possibility of a reverse current restriction is relatively low, drives the greatest adoption of the PV system. The near areas are primarily occupied by customers with only a PV to improve the diffusion rate of PVs via the self-organization by the communication between customers. It also leads to a decrease in the need for compensation devices, which in turn minimizes the social cost. Growth in the number of PVs in areas far from the transformer is assisted by the installation of batteries as compensation for the lost opportunity due to restrictions in those areas on reverse power currents. Therefore, excessive intervention by the government in the far areas results in an increase in the social cost of managing reverse currents.

15/00486 Assessing vanadium and arsenic exposure of people living near a petrochemical complex with two-stage dispersion models

Chio, C.-P. *et al. Journal of Hazardous Materials*, 2014, 271, 98–107.

The goal of this study is to demonstrate that it is possible to construct a two-stage dispersion model empirically for the purpose of estimating air pollution levels in the vicinity of petrochemical plants. Oil refineries and coal-fired power plants were studied in the No. 6 Naphtha Cracking Complex, an area of 2603 ha situated on the central west coast of Taiwan. The pollutants targeted were vanadium (V) from oil refineries and arsenic (As) from coal-fired power plants. A backward fitting method was applied to determine emission rates of V and As, with 192 PM₁₀ filters originally collected between 2009 and 2012. The first-stage model estimated emission rates of V and As (median and 95% confidence intervals at 0.0202 (0.0040–0.1063) and 0.1368 (0.0398–0.4782) g/s, respectively). In the second stage model, the predicted zone-average concentrations showed a strong correlation with V, but a poor correlation with As. The findings show that two-stage dispersion models are relatively precise for estimating V levels at residents' addresses near the petrochemical complex, but they did not work as well for As levels. In conclusion, the model-based approach can be widely used for modelling exposure to air pollution from industrial areas in countries with limited resources.

15/00487 Biodiesel production from *Jatropha* oil using mesoporous molecular sieves supporting K_2SiO_3 as catalysts for transesterification

Wu, H. *et al. Fuel Processing Technology*, 2014, 119, 114–120.
A series of solid base catalysts based on potassium salts (K_2CO_3 , K_2SiO_3 and KAc) supported on mesoporous silicas (SBA-15 and AISBA-15) were prepared by impregnation method and used to catalyse the transesterification of *Jatropha* oil with methanol. The prepared catalysts were characterized by several techniques such as X-ray diffraction, Brunauer–Emmett–Teller method, transmission electron microscopy and temperature-programmed desorption of CO_2 . In addition, various parameters affecting catalytic activity and biodiesel yield were investigated. The results showed that Al element dopant in SBA-15 could protect the pore structure of supported catalyst. The basicity and catalytic activity of AISBA-15 silica were improved significantly after loading potassium compounds. The activity of K_2SiO_3 impregnated catalyst was superior to those of K_2CO_3 and KAc impregnated catalysts. A biodiesel yield of 95% was obtained (using the K_2SiO_3 /AISBA-15 catalyst) with 30 wt% of K_2SiO_3 loading on AISBA-15 support, methanol/*Jatropha* oil molar ratio of 9, reaction temperature 60 °C, reaction time 150 min and catalyst/oil mass ratio 3%. Reuse of the catalyst indicated that the K_2SiO_3 /AISBA-15 had steady catalytic activity compared with traditional KOH and K_2CO_3 catalysts. After being reused for five cycles, a modest decrease of its activity led to a reduction of about 6% in the biodiesel yield. This decrease of catalytic activity was mainly caused by the potassium leaching and the adsorption of organic deposits on the catalyst surface.

15/00488 Calculation of electrostatically induced field in humans subjected to high voltage transmission lines

Talaat, M. *Electric Power Systems Research*, 2014, 108, 124–133.
A new approach is described for calculating the induced current and field in the human body by high-voltage alternating electric fields. The distribution of the electric field is obtained by using Laplace's equation. This relates the surface charge induced on the body to the potential in a reciprocal Laplace problem, which is then calculated by charge simulation method coupled with genetic algorithms to determine the appropriate arrangement of simulating charges inside the human body. The presented model for simulating electrical field is a three dimensional field problem and introduced different types of charges to simulate the different elementary geometrical shapes of human body. The particular strength of the charge simulation method in this application is its ability to allow a detailed representation of the shape and posture of the human body. The results have been assessed through comparison induced current and its distribution over the body surface, as estimated in other experimental and computational work. The accuracy of the simulated electric field is satisfied for the potential error (<0.1%), and the field deviation angle (<1°) over the human body.

15/00489 Characterization and optimization of biosurfactants produced by *Acinetobacter baylyi* ZJ2 isolated from crude oil-contaminated soil sample toward microbial enhanced oil recovery applications

Zou, C. *et al. Biochemical Engineering Journal*, 2014, 90, 49–58.
This study investigated the surface activity of the biosurfactant produced by *Acinetobacter baylyi* ZJ2 isolated from a crude oil-contaminated soil sample in China and evaluated its potential application in microbial enhanced oil recovery. The biosurfactant produced by *A. baylyi* ZJ2 was identified as lipopeptide, based on thin-layer chromatography, Fourier transform infrared spectroscopy and nuclear magnetic resonance techniques. This biosurfactant could reduce the surface tension of water from 65 to 35 mN/m, and interfacial tension against oil from 45 to 15 mN/m. Moreover, surface activity stability results showed that this biosurfactant was effective when the salinity was lower than 8% and the pH value was 4–9, and it was especially stable when the salinity was lower than 4% and pH was 6–7. Based on the result of gas chromatography, there was a decrease in heavy components and an increase in light components, which indicated that *A. baylyi* ZJ2 exhibited the biodegradability on the heavy components of crude oil. Furthermore, the ability of recovering oil from oil-saturated core showed that nearly 28% additional residual oil was displaced after water flooding. The lipopeptide biosurfactant produced by *A. baylyi* ZJ2 presented a great potential application in microbial enhanced oil recovery process, owing its good surface activity and satisfying degradation ability to crude oil.

15/00490 Daylighting offices: a first step toward an analysis of photobiological effects for design practice purposes

Bellia, L. *et al. Building and Environment*, 2014, 74, 54–64.
The research presented in this paper reports an analysis of daylight in three offices with different exposures and characteristics located in Naples, Italy. The goal was to fully investigate daylight characteristics, also considering the circadian impact of daylight entering these offices,

with the hope to develop guidelines to better assess daylight quality in built environments. One of the main findings of this research is that the spectral distributions and correlated colour temperatures of the light reaching the eye of a person seated at the desk in these offices are similar irrespective of the offices' different characteristics (dimensions, surfaces' spectral reflectances, external obstructions, etc.) and different sky's conditions. Moreover it was found that eye level irradiances and their circadian impact is similar to those of D50 and D55 CIE standard illuminants. The same measurements will be carried out in other seasons and a comparison between measured values and software simulated ones is also planned.

15/00491 DEA (data envelopment analysis) assessment of operational and environmental efficiencies on Japanese regional industries

Goto, M. *et al. Energy*, 2014, 66, 535–549.
A balance between industrial pollution and economic growth becomes a major policy issue to attain a sustainable society in the world. To discuss the problem from economics and business perspectives, this study proposes a new use of data envelopment analysis (DEA) as a methodology for unified (operational and environmental) assessment. A unique feature of the proposed approach is that it separates outputs into desirable and undesirable categories. Such separation is important because energy industries usually produce both desirable and undesirable outputs. This study discusses how to unify the two types of outputs under natural and managerial disposability. The proposed DEA approach evaluates various organizations by the three efficiency measures such as operational efficiency, unified efficiency under natural disposability and unified efficiency under natural and managerial disposability (UENM). An important feature of UENM is that it separates inputs into two categories and unifies them under the two disposability concepts in addition to the proposed output separation and unification. This study incorporates an amount of capital assets for technology innovation, as one of the two input group, into the measurement of UENM. Then, it compares UENM with the other two efficiency measures. This study is the first research effort in which DEA has an analytical capability to quantify the importance of investment on capital assets for technology innovation. To confirm the practicality of the proposed approach, this study applies the three efficiency measures to a data set regarding manufacturing and non-manufacturing industries of 47 prefectures in Japan. This study empirically confirms the validity of the Porter hypothesis in Japanese manufacturing industries, so implying that environmental regulation has been effective for betterment on the performance of Japanese manufacturing industries. Another important finding is that the emission of greenhouse gases is a main source of unified inefficiency in the two groups of industries. Therefore, Japanese industries, examined in this study, need to make their efforts to reduce the greenhouse gas emissions and air pollution substances by investing in capital assets for technology innovation.

15/00492 Discomfort glare in open plan green buildings

Hirning, M. B. *et al. Energy and Buildings*, 2014, 70, 427–440.
This study presents the largest-known, investigation on discomfort glare with 493 surveys collected from five green buildings in Brisbane, Australia. The study was conducted on full-time employees, working under their everyday lighting conditions, all of whom had no affiliation with the research institution. The survey consisted of a specially tailored questionnaire to assess potential factors relating to discomfort glare. Luminance maps extracted from high dynamic range images were used to capture the luminous environment of the occupants. Occupants who experienced glare on their monitor and/or electric glare were excluded from analysis leaving 419 available surveys. Occupants were more sensitive to glare than any of the tested indices accounted for. A new index, the unified glare probability (UGP) was developed to take into account the scope of results in the investigation. The index is based on a linear transformation of the unified glare rating (UGR) to calculate a probability of disturbed persons. However all glare indices had some correlation to discomfort, and statistically there was no difference between the daylight glare index, UGR and Commission Internationale de l'Éclairage glare index. The UGP broadly reflects the demographics of the working population in Australia and the new index is applicable to open plan green buildings.

15/00493 Does environmental regulation affect energy efficiency in China's thermal power generation? Empirical evidence from a slacks-based DEA model

Bi, G.-B. *et al. Energy Policy*, 2014, 66, 537–546.
Data envelopment analysis (DEA) has gained much popularity in performance measurement of power industry. This paper presents a slack-based measure approach to investigating the relationship between fossil fuel consumption and the environmental regulation of China's thermal power generation. The total-factor energy efficiency was calculated without considering environmental constraints. An environmental performance indicator was proposed through decom-

posing the total-factor energy efficiency. The proposed approach was then employed to examine whether environmental regulation affects the energy efficiency of China's thermal power generation. It was found that environmental efficiency plays a significant role in affecting energy performance of China's thermal generation sector. Decreasing the discharge of major pollutants can improve both energy performance and environmental efficiency. Besides, there were also three main findings: (1) the energy efficiency and environmental efficiency were relatively low, (2) the energy and environmental efficiency scores showed great variations among provinces, and (3) both energy efficiency and environmental efficiency were of obvious geographical characteristics. According to the findings, some policy implications were suggested.

15/00494 Dynamics of steel offshore platforms under ship impact

Travanca, J. and Hao, H. *Applied Ocean Research*, 2014, 47, 352–372.

This paper deals with the prediction of the dynamic response of steel offshore platforms to high-energy impacts from typical supply vessels. The contribution of the high modes of a cantilever beam type structure with a concentrated top mass subjected to transverse impact from rigid and deformable strikers is analysed. A procedure to develop simplified equivalent systems for efficient structural response analysis is presented and its reliability tested by comparing the results from the explicit non-linear finite element simulations. Effects such as the overall rotation of the installation, plastic deformations in the contact area, different impact locations and different hinge mechanisms are taken into account. It is shown that the use of the proposed equivalent systems with a reduced number of degrees of freedom (DOFs) can provide accurate results at significantly less computational efforts as compared to the finite element simulations. The derivation of some parameters of the equivalent dynamic elastic-plastic SDOF/2SDOF systems, however, needs to consider the complexity of the analysed steel frames and perform preliminary non-linear static analyses. Therefore, further studies of different impact scenarios on platforms with different configurations are recommended to augment the results presented here.

15/00495 Energy and carbon embodied in straw and clay wall blocks produced locally in the Andean Patagonia

González, A. D. *Energy and Buildings*, 2014, 70, 15–22.

The production and use of cereal straw as a base material to make building envelopes in the Andean Patagonian region have been investigated. Energy used and greenhouse gases (GHGs) emitted in local manufacturing of construction materials for walls based on wheat straw were obtained, as well as cropland required for different construction techniques. Two options for the use of straw to fill envelop walls were investigated: the direct use of straw bales, whether in whole or in halves, and the manufacturing of straw-clay blocks. The former has the best thermal conductivity but requires larger cultivation areas to satisfy wall demands, while the latter could be an option including moderate thermal efficiency and better cropland performance. Per wall surface unit, energy use and GHG emissions of all straw options were significantly lower compared to fired bricks or to concrete blocks. Furthermore, all straw options analysed result in significantly better thermal performance than current choices of fired bricks or concrete blocks, which are commonly used in the region. The present results show a relevant role of renewable agricultural products in lowering impacts of building materials, as well as options for sustainable production.

15/00496 Engaging the public with low-carbon energy technologies: results from a Scottish large group process

Howell, R. *et al. Energy Policy*, 2014, 66, 496–506.

This paper presents the results of a large group process conducted in Edinburgh, Scotland, investigating public perceptions of climate change and low-carbon energy technologies, specifically carbon dioxide capture and storage (CCS). The quantitative and qualitative results reported show that the participants were broadly supportive of efforts to reduce carbon dioxide emissions, and that there is an expressed preference for renewable energy technologies to be employed to achieve this. CCS was considered in detail during the research due to its climate mitigation potential; results show that the workshop participants were cautious about its deployment. The paper discusses a number of interrelated factors which appear to influence perceptions of CCS; factors such as the perceived costs and benefits of the technology, and people's personal values and trust in others all impacted on participants' attitudes towards the technology. The paper thus argues for the need to provide the public with broad-based, balanced and trustworthy information when discussing carbon dioxide capture and storage, and to take seriously the full range of factors that influence public perceptions of low-carbon technologies.

15/00497 Evaluation of bus emissions generated near bus stops

Yu, Q. and Li, T. *Atmospheric Environment*, 2014, 85, 195–203.

The purpose of this research is to demonstrate a methodology for quantification of bus emissions generated near bus stops based on the real-world on-road emissions data collected by the portable emission measurement system (PEMS). Data collection was carried out on an urban diesel bus throughout a bus line under normal operation condition on four work days. Stop influence zone is defined as the area in which the normal bus driving is interrupted by bus stops. The second-by-second data were screened out within the stop influence zone. And the bus running state near a stop was classified into three driving modes, deceleration, idling, and acceleration. Then emission characteristics were analysed for each mode. Under the idling condition, the emission rates (g s^{-1}) were not constant all the time. The NO_x emission rate decreased in the first 4–6 s while the corresponding emission rates of CO_2 , CO , NO_x , and HC increased in the last 4 s of idling. The influence of bus stop characteristics on emissions was also investigated using statistical methods. Platform type, length and location of bus stops showed significant effects on the length of the stop influence zone. However, there were no significant effects on distance-based emission factors.

15/00498 Health impacts due to personal exposure to fine particles caused by insulation of residential buildings in Europe

Gens, A. *et al. Atmospheric Environment*, 2014, 84, 213–221.

The insulation of residential buildings affects human exposure to fine particles. According to current European Union guidelines, insulation is regulated for energy saving reasons. As buildings become tighter, the air exchange rate is reduced and, thus, the indoor concentration of pollutants is increased if there are significant indoor sources. While usually the effects of heat insulation and increase of the air-tightness of buildings on greenhouse gas emissions are highlighted, the negative impacts on human health due to higher indoor concentrations are not addressed. Thus, these impacts were investigated using scenarios in three European countries, i.e. Czech Republic, Switzerland and Greece. The assessment was based on modelling the human exposure to fine particles originating from sources of particles within outdoor and indoor air, including environmental tobacco smoke. Exposure response relationships were derived to link (adverse) health effects to the exposure. Furthermore, probable values for the parameters influencing the infiltration of fine particles into residential buildings were modelled. Results show that the insulation and increase of the air-tightness of residential buildings leads to an overall increase of the mean population exposure – and consequently adverse health effects – in all considered countries (ranging for health effects from 0.4% in Czech Republic to 11.8% in Greece for 100% insulated buildings) due to an accumulation of particles indoors, especially from environmental tobacco smoke. Considering only the emission reductions in outdoor air (omitting changes in infiltration parameters) leads to a decrease of adverse health effects. This study highlights the importance of ensuring a sufficient air exchange rate when insulating buildings, e.g. by prescribing heat ventilation and air conditioning systems in new buildings and information campaigns on good airing practice in renovated buildings. It also shows that assessing policy measures based on the exposure may provide different recommendations compared to an assessment based on only the outdoor air concentration.

15/00499 Health risk assessment for residents exposed to atmospheric diesel exhaust particles in southern region of Taiwan

Chio, C.-P. *et al. Atmospheric Environment*, 2014, 85, 64–72.

Evidence shows a strong association among air pollution, oxidative stress (OS), deoxyribonucleic acid (DNA) damage, and diseases. Recent studies indicated that the aging, human neurodegenerative diseases and cancers resulted from mitochondrial dysfunction and OS. The purpose of this study is to provide a probabilistic risk assessment model to quantify the atmospheric diesel exhaust particles (DEP)-induced pre-cancer biomarker response and cancer incidence risk for residents in south Taiwan. The authors conducted entirely monthly particulate matter sampling data at five sites in Kaohsiung of south Taiwan in the period 2002–2003. Three findings were found: (i) the DEP dose estimates and cancer risk quantification had heterogeneously spatiotemporal difference in south Taiwan, (ii) the pre-cancer DNA damage biomarker and cancer incidence estimates had a positive yet insignificant association, and (iii) all the estimates of cancer incidence in south Taiwan populations fell within and slight lower than the values from previous cancer epidemiological investigations. This study successfully assessed the tumour incidence for residents posed by DEP exposure in south Taiwan compared with the epidemiological approach. The approach provides a unique way for assessing human health risk for residences exposed to atmospheric DEP depending on specific combinations of local and regional conditions. This work

implicates the importance of incorporating both environmental and health risk impacts into models of air pollution exposure to guide adaptive mitigation strategies.

15/00500 Impacts of NMVOC emissions on human health in European countries for 2000–2010: use of sector-specific substance profiles

Laurent, A. and Hauschild, M. Z. *Atmospheric Environment*, 2014, 85, 247–255.

Non-methane volatile organic compounds (NMVOC) are known to cause damage to human health by two main pathways: direct toxic effects exerted by certain substances (termed human toxicity) and their indirect effects related to photochemical ozone formation (POF). To comprehensively assess the damage at a national level and thus define adequate air pollution abatement policies, substance breakdowns are needed. However, these are not readily available as total NMVOC emissions are only reported at sector level. This study developed a reproducible methodology that combines available speciation profiles, i.e. distributions of substances emitted per type of sources, and sectoral NMVOC information to reach country-specific, substance-specific emission profiles. Annual emission inventories, including 270 single substances and 52 unrefined groups of substances, were determined for 31 European countries within the period 2000–2010. Using life cycle impact assessment methods for POF and human toxicity, impacts on human health were quantified. The results indicated that a strong linear correlation exists between POF impacts and the total NMVOC emissions, suggesting that air pollution abatement policies could use total NMVOC emissions as a proxy for reducing these impacts. Despite underlying uncertainties, the results also demonstrated that the POF impacts from NMVOC are negligible compared to their direct toxic impacts. The analysis of the results revealed that the toxic impacts (i) are caused by few substances, such as formaldehyde, acrolein and furan, (ii) primarily stem from transportation sectors and from residential sources and (iii) are found not to correlate with total NMVOC emissions. The findings therefore suggest the need for supporting air pollution abatement strategies with comprehensive impact assessments, which, in addition to complementing emission- and concentration-based indicators, should allow identifying country-specific improvement potentials at substance and sector levels.

15/00501 Implications of global warming for commercial building retrofitting in Australian cities

Daly, D. et al. *Building and Environment*, 2014, 74, 86–95.

Retrofit strategies for commercial buildings are generally selected with the assumption of a stationary climate, despite the fact that the building will be operating for much of its life in a climate altered by global warming. This paper presents the results of detailed energy simulations of the possible impact of climate change on the energy consumption of an archetypal commercial office building in five Australian cities, and the relative magnitude of this impact compared to other possible changes to building energy consumption. The question of whether climatic change due to global warming is an important factor when selecting optimal retrofit strategies was considered in the present study, using predictive weather files generated from the Intergovernmental Panel on Climate Change (IPCC) projections for 2020, 2050 and 2080. In regions without a substantial heating demand an increase in total building energy consumption was found, and when a substantial heating load was present a slight increase or decrease in energy consumption was observed. Changes in total building energy consumption of between –0.6% and +8.3%, and an increase in the total design cooling equipment capacity of 9.1–25.0% was predicted over the period 1990 to 2080 due to climate change for the different cities. It was concluded that future climate change impacts are not as significant in the design and assessment of retrofit strategies for commercial office buildings as other impacts, as changes to building construction and usage will likely impact energy consumption much more significantly.

15/00502 Improvement of air quality forecasts with satellite and ground based particulate matter observations

Hirtl, M. et al. *Atmospheric Environment*, 2014, 84, 20–27.

Daily regional scale forecasts of particulate air pollution are simulated for public information and warning. An increasing amount of air pollution measurements is available in real-time from ground stations as well as from satellite observations. In this paper, the support vector regression technique is applied to derive highly-resolved particulate matter <10 μ m (PM10) initial fields for air quality modelling from satellite measurements of the aerosol optical thickness. Additionally, PM10-ground measurements are assimilated using optimum interpolation. The performance of both approaches is shown for a selected PM10 episode.

15/00503 Inducing [sub]conscious energy behaviour through visually displayed energy information: a case study in university accommodation

Chiang, T. et al. *Energy and Buildings*, 2014, 70, 507–515.

Direct feedback on energy use presented by in-home displays has been found to be useful in helping people learn about their energy use and make a reduction. However, it is not yet clear what is the best form in which to present energy information. Two 6-week experiments were carried out in student residences at the University of Bath, UK, to investigate how visually displayed energy information presented in different ways could encourage reductions in energy use. Experiment 1 compared three energy display interface designs (one giving numerical information, one using analogue dials and one using emotional faces) all presenting the same information. This resulted in a 7.7% savings over baseline. Experiment 2 examined how well participants responded to ranking information in numerical format about their own consumption. This resulted in a 2.5% reduction from baseline. Although there was a trend towards the ambient faces display performing best, all the displays led to a reduction in energy use. A significant decrease in consumption was also seen in the groups that saw ranking information, whether compared to their baseline consumption or to the control groups. In conclusion, it would appear that the mere presence of a display device can reduce energy use, even when participants are not engaged with the display.

15/00504 Is environmental efficiency trade inducing or trade hindering?

Doganay, S. M. et al. *Energy Economics*, 2014, 44, 340–349.

Global efforts to identify strategies for sustainable economic growth and development underline the need for understanding important links between environmental policies and international trade. In this paper, by constructing an environmental efficiency index for 111 countries from 1980 to 2009, the authors were able to test empirically for one such link. An improvement in the environmental efficiency index in terms of carbon dioxide emissions reflects a decrease in the cost of efforts to mitigate the environmental costs associated with growth. Countries that improve their environmental efficiency are found to experience strong international trade effects, both through increased exports and increased imports. While the positive link between efficiency improvements and exports is supportive of the Porter hypothesis, the positive link between efficiency improvements and imports is supportive of strong positive income effects on account of environmental efforts. These results, which are robust to alternative estimation strategies, lend strong support to global efforts to improve countries' environmental efficiencies.

15/00505 Land use change, fuel use and respiratory health in Uganda

Jagger, P. and Shively, G. *Energy Policy*, 2014, 67, 713–726.

This paper examines how biomass supply and consumption are affected by land use change in Uganda. It was found that between 2007 and 2012 there was a 22% reduction in fuelwood sourced from proximate forests, and an 18% increase in fuelwood sourced from fallows and other areas with lower biomass availability and quality. Estimating a series of panel regression models found that deforestation has a negative effect on total fuel consumed. It was also found that access to forests, whether through ownership or proximity, plays a large role in determining fuel use. An investigation was then carried out into whether patterns of biomass fuel consumption were related to the incidence of acute respiratory infection (ARI) using a cross-sectional data set of 1209 women and 598 children. A positive and significant relationship was found between ARI and the quantity of fuelwood from non-forest areas; a 100kg increase in fuelwood sourced from a non-forest area results in a 2.4% increase in the incidence of ARI for children. It was also found that individuals in households that use larger quantities of crop residues are less likely to have symptoms of AR. As deforestation reduces the availability of high-quality fuelwood, rural households may experience higher incidence of health problems associated with exposure to biomass burning.

15/00506 Measuring the effect of procrastination and environmental awareness on households' energy-saving behaviours: an empirical approach

Lillemo, S. C. *Energy Policy*, 2014, 66, 249–256.

A common finding in behavioural economics is that people often procrastinate, i.e. keep postponing planned tasks or decisions that require effort to execute. The effect of procrastination on inter-temporal energy choice behaviours could be even more serious because energy is an abstract, invisible and intangible commodity. This paper uses a web survey to investigate how people's procrastination propensity and environmental awareness affect their heating-energy-saving behaviours. The results indicate that people who state that they have a higher tendency to procrastinate are significantly less likely to have engaged in most of the heating energy-saving activities, especially regarding larger purchases or investments in equipment and the

insulation of doors and windows. A positive relationship was found between environmental awareness and engaging in everyday energy-saving activities such as reducing the indoor temperature. The findings suggest that measures aimed at reducing procrastination are needed to realize energy-saving potential. It is important to find ways to either bring future benefits closer to the present or to magnify the costs of delayed action. For example, one can employ certain feedback systems and commitment devices to make current gains and future costs more visible or tangible.

15/00507 Mitigating climate change: decomposing the relative roles of energy conservation, technological change, and structural shift

Mishra, G. S. *et al. Energy Economics*, 2014, 44, 448–455.

This study decomposes the contribution of five drivers of energy use and CO₂ emissions reductions in achieving climate change goals over 2005–2100 for various climate policy scenarios. This study contributes to the decomposition literature in three ways. First, it disaggregated drivers of energy demand into technological progress and demand for energy services, represented in terms of useful energy, allowing us to estimate their contributions independently – an improvement over other economy-wide decomposition studies. Secondly, this approach reduced the ambiguity present in many previous measures of structural change. Structural shifts were delineated into two separate measures: changes in fuel mix within a given resource or service pathway; and changes in mix among distinct energy resources or end-use services. Finally, this study applied decomposition methods to energy and emission trajectories from two mutually informing perspectives: (i) primary energy resources – crude oil, natural gas, coal, nuclear, and renewables; and (ii) end-uses of energy services – residential and commercial buildings, industry, and transportation. The results show that technological improvements and energy conservation are important in meeting climate goals in the first half of the coming century; and that nuclear and renewable energy and CO₂ capture and storage technology are crucial in meeting more stringent goals in the second half of the century. The relative roles of the drivers in reducing CO₂ emissions were examined separately for developed and developing regions. Although the majority of energy and emission growth – and by extension the greatest opportunities for mitigation – will occur in developing countries, the decomposition shows that the relative roles of the five drivers are broadly consistent between these two regions.

15/00508 Public attitudes towards renewable energy technologies in Norway. The role of party preferences

Karlstrøm, H. and Ryghaug, M. *Energy Policy*, 2014, 67, 656–663.

Transition to a sustainable society requires large-scale conversion of the energy system to new, renewable, non-fossil sources of energy. This presupposes public support for new technologies, which means the public must deal with challenges in terms of placement, area requirements, ecological degradation and price developments. This paper discusses how citizens view renewable energy technologies. It analyses responses to representative surveys of the Norwegian population on the desirability of various energy technologies such as hydroelectric dams, onshore and offshore wind energy, bioenergy plants and, for contrast, gas plants with and without carbon capture and storage. The main focus is on the influence of party political preference on views of renewable energy. It was found that the sometimes lukewarm enthusiasm for renewable energy technologies cannot be fully explained by existing theories and that political party preference has a larger impact on energy technology attitudes than previously believed.

15/00509 Strategic environmental assessment of energy planning tools. A study of Italian regions and provinces

De Montis, A. *Environmental Impact Assessment Review*, 2014, 46, 32–42.

Strategic environmental assessment (SEA) has been applied in different ways in European Union energy and environmental planning instruments, because different member states have interpreted European Directive 2001/42/CE in a variety of ways. Italy, for example, has only recently completed the integration of the directive into its legislation, through a number of decrees which were approved between 2006 and 2010. As a result SEA practice in Italy is very fragmented, particularly with respect to energy planning, and needs to be steered towards homogeneous quality objectives. The aim of this paper is to study the quality of the SEA reports on the energy and environmental planning tools used by Italian regions and provinces. Nine cases were studied, using the methodology suggested by Fisher in his earlier review of the quality of SEA. To be more precise, the views of external evaluators were integrated with those of a selection of the personnel directly involved in preparing the plans. The results show that there are some differences in the quality scores given by the outsiders and insiders, although the two groups identified similar strengths and weaknesses in implementing SEA.

15/00510 Support for the integration of green roof constructions within Chinese building energy performance policies

Kokogiannakis, G. and Darkwa, J. *Energy*, 2014, 65, 71–79.

Green roofs could act as a thermal buffer in buildings and offer potential energy savings. However, the energy benefits from green roofs are not usually properly recognized by traditional building energy regulations. Building energy regulations are traditionally over-simplistic during the assessment of the energy performance of complex building constructions. In the case of green roof designs, it is essential that the assessment mechanisms should not ignore the complex heat and moisture balances within the green roof layers. In this paper, dynamic energy modelling that considers the complexity within the green roof layers is adopted to guide policy makers in China on the relationship between using specific thicknesses of roof insulation against green roof layers. Simulations are run for a residential building type by also considering different thermal envelope characteristics across eight large Chinese cities and within the five main climatic zones of China. Results that link the green roof characteristics with respective traditional insulation layers are produced for all cities and it is found that optimizing the plant and soil characteristics of green roofs in some climates could substitute more than 125 mm of roof insulation, while less optimum green roof types could only replace about 25 mm of roof insulation.

15/00511 The contextual factors contributing to occupants' adaptive comfort behaviors in offices – a review and proposed modeling framework

O'Brien, W. *et al. Burak Gunay, H. Building and Environment*, 2014, 77, 77–87.

Occupants play an unprecedented role on energy use of office buildings and they are often perceived as one of the main causes of under-performing buildings. It is therefore necessary to capture the factors influencing these energy intensive occupant behaviours and to incorporate them in building design. This review-based article puts forward a framework to represent occupant behaviour in buildings by arguing: occupants are not illogical and irrational but rather that they attempt to restore their comfort in the easiest way possible, but are influenced by many contextual factors. This framework synthesizes statistical and anecdotal findings of the occupant behaviour literature. Furthermore, it lends itself to occupant behaviour researchers to form a systematic way to report the influential contextual factors such as ease of control, freedom to reposition, and social constraints.

15/00512 The cooling effect of urban green spaces as a contribution to energy-saving and emission-reduction: a case study in Beijing, China

Zhang, B. *et al. Building and Environment*, 2014, 76, 37–43.

Urban green spaces have been proven to significantly decrease ambient air temperature and mitigate heat islands created by urbanization. However, the environmental benefits of cooling provided by urban green spaces have rarely been measured. This study estimated the energy-savings and emission-reduction contribution of urban green spaces in Beijing, applying an empirical model. The calculations suggest urban green spaces play a major role in reducing energy demand and increasing CO₂ sequestration. Urbanized Beijing has 16,577 ha of green space which could absorb 3.33×10^{12} kJ of heat via evapotranspiration during the entire summer. The cooling effect reduced the air conditioning demand by 3.09×10^8 kWh which amounts to a 60% reduction in net cooling energy usage in Beijing. The annual reduction in CO₂ emissions from power plants associated with electricity saving would reach 243,000 tons with an average of 61 kg/(ha day). Also, the cooling effect and the environmental benefits of urban green space in Beijing largely depend on the green space's structure and size. Urban managers and landscape planners should take advantage of this research to plan, design and manage green spaces in heat island areas.

15/00513 The development of a multi-surface soil speciation model for Cd (II) and Pb (II): comparison of two approaches for metal adsorption to clay fractions

Gu, X. *et al. Applied Geochemistry*, 2014, 47, 99–108.

The mobility of toxic metals in soils or sediments is of great concern to scientists and environmentalists since it directly affects the bioavailability of metals and their movement to surface and ground waters. In this study, a multi-surface soil speciation model for Cd(II) and Pb(II) was developed to predict the partition of metals on various soil solid components [e.g. soil organic matter (SOM), oxide mineral, and clay mineral]. In a previous study, the sorption of metal cations on SOM and oxide minerals has been evaluated by a thermodynamically based surface complexation model. However, metal binding to soil clay fractions was normally treated in a simplistic manner: only cation exchange reactions were considered and exchange coefficient was assumed as unity. In this study, the binding of metals onto clays was described by a two-site surface sorption model (a basal surface site and

an edge site). The model was checked by predicting the adsorption behaviour of Cd(II) and Pb(II) onto three selected Chinese soils as a function of pH and ionic strengths. Results showed that the proposed model more accurately predicted the metal adsorption on soils under studied condition, especially in low ionic strength condition, suggesting that adsorption of metals to soil clay fractions need to be considered more carefully when modelling the partition of trace elements in soils. The developed soil speciation model will be useful when evaluating the movement and bioavailability of toxic metals in soil environment.

15/00514 The impact of the household decision environment on fuel choice behavior

van der Kroon, B. *et al. Energy Economics*, 2014, 44, 236–247.

Consumer preferences for fuels and alternative cookstove technologies in Kenya are examined, focusing on household internal and external determinants driving choice behaviour in a choice experiment. The potential for a transition towards cleaner and more efficient fuels and technologies is assessed by zooming in on three fuel-stove combinations. Substantial demand and positive willingness to pay were found for the fuel-stove combinations in three locations representing different decision environments. Demand is significantly higher in the peri-urban and the resource abundant rural location than in the resource scarce rural location. The presence of better-developed consumer markets for fuels in these locations functions as an important driver for cookstove adoption. Although charcoal and ethanol stoves are preferred over improved firewood stoves, continued firewood usage is expected. Energy switching behaviour cannot be substantiated. Instead, energy stacking is more likely, where charcoal and ethanol add to and extend a household's energy portfolio.

15/00515 The windy city: property value impacts of wind turbines in an urban setting

Lang, C. *et al. Energy Economics*, 2014, 44, 413–421.

This paper examines the impact of wind turbines on house values in Rhode Island, USA. In contrast to wind farms surrounded by sparse development, in Rhode Island single turbines have been built in relatively dense high population areas. As a result, 48,554 single-family, owner-occupied transactions were observed within 5 miles of a turbine site, including 3254 within 1 mile, which is far more than most related studies. The authors estimated hedonic difference-in-differences models that allow for impacts of wind turbines by proximity, viewshed, and contrast with surrounding development. Across a wide variety of specifications, the results suggest that wind turbines have no statistically significant negative impacts on house prices, in either the post-public announcement phase or post-construction phase. Further, the lower bound of statistically possible impacts is still outweighed by the positive externalities generated from CO₂ mitigation.

15/00516 What do people living in deprived communities in the UK think about household energy efficiency interventions?

Scott, F. L. *et al. Energy Policy*, 2014, 66, 335–349.

While physical interventions such as external wall cladding can improve the energy efficiency of domestic properties, how residents think about and respond to such interventions can influence both their uptake and impact on the household's energy use. The present research investigated what residents living within deprived communities in Yorkshire and the Humber in northern England thought about a number of household energy efficiency interventions proposed as part of a project known as 'The BIG Energy Upgrade'. The theory of planned behaviour was used as a framework for investigating residents' beliefs. Residents generally felt positive about the proposed interventions and expected that they would lead to financial savings, improve the appearance and warmth of their homes, and sense of pride in the local community. However, while residents intended to adopt energy efficiency interventions if offered them, they were less willing to personally invest in them. Home ownership and the belief in humans' ability to tackle climate change were found to predict willingness to invest. These findings help to understand responses to initiatives that seek to improve the energy efficiency of hard-to-treat homes.

CO₂, NO_x, SO₂ and particulate emissions

15/00517 3D geomechanical modeling for CO₂ geological storage in faulted formations. A case study in an offshore northern Adriatic reservoir, Italy

Teatini, P. *et al. International Journal of Greenhouse Gas Control*, 2014, 22, 63–76.

One of the six CO₂ carbon capture and storage (CCS) demonstration projects recently selected within the European Energy Programme for Recovery (EEPR) is located in Italy. In the framework of the feasibility study, the selection of a geological formation suitable to store the required 1 Mt/yr of CO₂ over 10 years and the safety of the CO₂ disposal are two major issues. This study investigates the role played by geomechanics in assessing the maximum CO₂ amount that can be sequestered into a 2000 m deep multi-compartment reservoir seated in the off-shore northern Adriatic sedimentary basin. A three-dimensional finite element–interface element geomechanical model was used to simulate the possible mechanical failure in both the injected formation and caprock, the fault reactivation, and the ground surface displacement. The faulted geological structure is reproduced based on detailed seismic surveys, with petrophysical/geomechanical properties based on the several well-logs available from several oil/gas explorations in the area. The pore pressure distribution due to two injection wells is provided by a fluid-dynamic simulator and a sensitivity analysis is carried out to investigate the role of the major uncertainties in the geomechanical setting. The modelling results suggest that a safe and permanent containment may be secured over a few years only. Afterwards, mechanical failure by shear stress is likely to be experienced by a significant portion of reservoir's injected compartments. Shear failure and fault reactivation can occur much before attaining the hydraulic fracturing pressure, hence represent two major issues in assessing the maximum allowable CO₂ injection overpressure.

15/00518 Characteristics of nitrous oxide (N₂O) emission from intermittently aerated sequencing batch reactors (IASBRs) treating slaughterhouse wastewater at low temperature

Pan, M. *et al. Biochemical Engineering Journal*, 2014, 86, 62–68.

This study investigated the characteristics of nitrous oxide (N₂O) emission from intermittently aerated sequencing batch reactors (IASBRs) treating high strength slaughterhouse wastewater at 11 °C, where partial nitrification followed by denitrification (PND) was achieved. N₂O generation and emission was examined at three aeration rates of 0.4, 0.6 and 0.8 L air/min in three IASBRs (SBR1, SBR2 and SBR3, respectively). The slaughterhouse wastewater contained chemical oxygen demand (COD) of 6057 ± 172.6 mg/L, total nitrogen (TN) of 576 ± 15.1 mg/L, total phosphorus (TP) of 52 ± 2.7 mg/L and suspended solids (SS) of 1843 ± 280.5 g/L. In the pseudo-steady state, the amount of N₂O emission was up to 5.7–11.0% of incoming TN. The aeration rate negatively affected N₂O emission and the ratio of N₂O emission to incoming TN was reduced by 48.2% when the aeration rate was increased from 0.4 to 0.8 L air/min. Results showed that more N₂O was generated in non-aeration periods than in aeration periods. Lower DO concentrations enhanced N₂O generation in the aeration periods (probably via nitrifier denitrification) while low DO concentrations (lower than 0.2 mg/L) did not affect N₂O generation in the non-aeration periods (probably via heterotrophic denitrification). When PHB was utilized as the organic substrate for denitrification, there was a high N₂O generation potential. It was estimated that 1.8 mg N₂O-N was generated accompanying per mg PHB consumed.

15/00519 Convergence of carbon dioxide emissions in different sectors in China

Wang, J. and Zhang, K. *Energy*, 2014, 65, 605–611.

This study analyses differences in per capita carbon dioxide emissions from 1996 to 2010 in six sectors across 28 provinces in China and examines the σ -convergence, stochastic convergence and β -convergence of these emissions. The factors that impact the convergence of per capita carbon dioxide emissions in each sector are also investigated. The results show that per capita carbon dioxide emissions in all sectors converged across provinces from 1996 to 2010. Factors that impact the convergence of per capita carbon dioxide emissions in each sector vary: gross domestic product (GDP) per capita, industrialization process and population density impact convergence in the industry sector, while GDP per capita and population density impact convergence in the transportation, storage, postal, and telecommunications services sector. Aside from GDP per capita and population density, trade openness also impacts convergence in the wholesale, retail, trade, and catering service sectors. Population density is the only factor that impacts convergence in the residential consumption sector.

15/00520 Development of a high efficient gas to hydrate (GTH) conversion process using SDS kinetic promoter for maximizing the CO₂ recovery with minimum energy consumption

ZareNezhad, B. and Montazeri, V. *Energy Conversion and Management*, 2014, 79, 289–293.

In this work the optimum operating conditions for complete carbon dioxide recovery via gas to hydrate conversion process with minimum energy consumption is investigated. A new series of experiments are carried out at different pressures, temperatures, agitation intensities and kinetic promoter concentrations by using a newly developed fully

automated gas-to-hydrate energy converter. According to the presented results at the 27 bar and 1 °C and in the presence of 4000 ppm anionic surfactant sodium dodecyl sulfate and proper amount of free water, it is possible to reach a CO₂ gas to hydrate conversion of 95% without using any agitating device and without using any help additive at a completely unstirred quiescent condition which is a superb result from engineering viewpoint. The presented approach outperforms the other energy consuming CO₂ recovery processes and can have significant industrial application for development of low cost hydrate-based carbon dioxide recovery plants.

15/00521 Effect of reactive surface area of minerals on mineralization and carbon dioxide trapping in a depleted gas reservoir

Bolourinejad, P. *et al. International Journal of Greenhouse Gas Control*, 2014, 21, 11–22.

In this study, a long-term (up to 1000 years) geochemical modelling of subsurface CO₂ storage was carried out on sandstone reservoirs of depleted gas fields in north-east Netherlands. It was found that mineral dissolution/precipitation has only a minor effect on reservoir porosity. In order to validate this, the authors focused specifically on the reactive surface area of minerals measured by scanning electron microscopy. In this way distributions were obtained for the measured reactive surface areas of each individual mineral. Subsequent parameter analysis and Monte Carlo sampling of these distributions revealed that in the Rotliegend sandstones, the surface area of quartz has by far the largest effect on SMC_{CO2} (total amount of CO₂ sequestered as mineral). The proportional relation of SMC_{CO2} and quartz reactive surface area leads to the conclusion that CO₂ injection in a sandstone reservoir with fine-grained quartz has a higher potential for mineral trapping of CO₂. In addition, using parameter analysis, the effect of surface area of each mineral on its own dissolution/precipitation mechanisms could also be determined as well as on the other minerals. For example, the results showed that dawsonite precipitation is proportional to kaolinite and K-feldspar surface area.

15/00522 Evaluation of on-road vehicle CO and NO_x National Emission Inventories using an urban-scale source-oriented air quality model

Kota, S. H. *et al. Atmospheric Environment*, 2014, 85, 99–108.

The MOBILE6.2 model was replaced by the Motor Vehicle Emission Simulator (MOVES) in 2012 as an official tool recommended by the US Environmental Protection Agency (EPA) to predict vehicular pollutant emission factors. In this study, on-road vehicle emission inventories of CO and NO_x for southeast Texas generated by MOVES and MOBILE6.2 in two versions of the 2005 National Emission Inventory (NEI) were studied by comparing predicted CO and NO_x using the EPA's Community Multiscale Air Quality (CMAQ) model incorporated with a source-oriented gas phase chemical mechanism with measurements made at six urban and industrial sites in southeast Texas. The source tracing technique allows direct determination of contributions of on-road vehicles to overall CO and NO_x concentrations and identification of ambient concentration measurements which are mostly impacted by vehicle emissions. By grouping the fractional bias (FB) values of the hourly predictions based on vehicle contributions to total CO or NO_x concentrations, clear trends in the FB were observed, indicating systematic biases in the emission inventory for these species. Data points dominated by vehicle emissions suggest that surface CO concentrations due to vehicle exhaust are significantly over-estimated by a factor of two using either MOVES or MOBILE6.2. NO_x concentrations are overestimated by approximately 20–35% and 70% by using the MOBILE6.2 and MOVES emissions, respectively. Emission scaling runs show that a domain-wide reduction of MOBILE6.2 CO emissions by 60% and NO_x emissions by 15–25% leads to better model performance of exhaust CO and NO_x concentrations in the current study.

15/00523 Experimental study of gas evolution in heterogeneous shallow subsurface formations during leakage of stored CO₂

Plampin, M. *et al. International Journal of Greenhouse Gas Control*, 2014, 22, 47–62.

A concern for geologic carbon sequestration is the potential for stored CO₂ to leak upward into valuable shallow aquifers where it can cause potentially detrimental impacts to groundwater resources. Understanding the mechanisms of CO₂ migration and predicting its movement in shallow aquifers is a critical part of determining those impacts. During leakage, CO₂ dissolved in brines may travel upward, potentially causing the gas to be released from solution (exsolve). Exsolved gas may accumulate at soil layer transitions, or flow into the vadose zone and ultimately the atmosphere. For this study, a series of intermediate-scale laboratory experiments were conducted to observe CO₂ gas evolution in heterogeneous porous media. Results indicate that: (1) heterogeneous interfaces as well as flow constrictions through discontinuities in low-permeability layers enhance the evolution of gas

phase, provided the water pressure at those layers is less than the pressure at which the flowing water was saturated with CO₂, (2) higher contrast between the sands in a one-dimensional heterogeneous system leads to faster gas evolution, and (3) the effects of water flow rate on the evolution of the gas phase are sensitive to two-dimensional water flow pattern fluctuations.

15/00524 High-resolution stable carbon isotope monitoring indicates variable flow dynamic patterns in a deep saline aquifer at the Ketzin pilot site (Germany)

Nowak, M. E. *et al. Applied Geochemistry*, 2014, 47, 44–51.

Stable isotopes of injected CO₂ act as useful tracers in carbon dioxide capture and storage (CCS) because the CO₂ itself is the carrier of the tracer signal and remains unaffected by sorption or partitioning effects. At the Ketzin pilot site (Germany), carbon stable isotope composition (δ¹³C) of injected CO₂ at the injection well was sampled over a time period of 4 months. Occurring isotope variances resulted from the injection of CO₂ from two different sources (an oil refinery and a natural gas-reservoir). The two gases differed in their carbon isotope composition by more than 27‰. In order to find identifiable patterns of these variances in the reservoir, more than 250 CO₂-samples were collected and analysed for their carbon isotope ratios at an observation well 100 m distant from the injection well. An isotope ratio mass spectrometer connected to a modified thermo gasbench system allowed quick and cost effective isotope analyses of a high number of CO₂ gas specimens. CO₂ gas from the oil refinery (δ¹³C = −30.9‰, source A) was most frequently injected and dominated the reservoir δ¹³C values at the injection site. Sporadic injection of the CO₂ from the natural gas-reservoir (δ¹³C = −3.5‰, source B) caused isotope shifts of up to +5‰ at the injection well. These variances provided a potential ideal tracer for CO₂ migration behaviour. Based on these findings, tracer input signals that were injected during the last 2 years of injection could be reconstructed with the aid of an isotope mixing model and CO₂ delivery schedules. However, in contrast to the injection well, δ¹³C values at the observation well showed no variances and a constant value of −28.5‰ was measured at 600 m depth. This is in disagreement with signals that would be expected if the input signals from the injection would arrive at the observation well. The lack of isotope signals at the observation well suggests that parts of the reservoir are filled with CO₂ that is immobilized.

15/00525 Methanol absorption characteristics for the removal of H₂S (hydrogen sulfide), COS (carbonyl sulfide) and CO₂ (carbon dioxide) in a pilot-scale biomass-to-liquid process

Seo, M. W. *et al. Energy*, 2014, 66, 56–62.

The biomass-to-liquid (BTL) process is an attractive process that produces liquid biofuels from biomass. The Fischer-Tropsch (FT) process is used to produce syngas such as diesel and gasoline from gasified biomass. However, the hydrogen sulfide (H₂S), carbonyl sulfide (COS) and carbon dioxide (CO₂) in the syngas that are produced from the biomass gasifiers cause a decrease of the conversion efficiency and deactivates the catalyst that is used in the FT process. To remove the acid gases, a pilot-scale methanol absorption tower producing diesel at a rate of one barrel per day was developed, and the removal characteristics of the acid gases were determined. A total operation time of 500 h was achieved after several campaigns. The average syngas flow rate at the inlet of methanol absorption tower ranged from 300 to 800 L/min. The methanol absorption tower efficiently removed H₂S from 30 ppmV to less than 1 ppmV and COS from 2 ppmV to less than 1 ppmV with a removal of CO₂ from 20% to 5%. The outlet gas composition adhered to the guidelines for FT reactors. No remaining sulfurous components were found, and the tar component was analysed in the spent methanol after long-term operations.

15/00526 Mitigation and remediation technologies and practices in case of undesired migration of CO₂ from a geological storage unit – current status

Manceau, J.-C. *et al. International Journal of Greenhouse Gas Control*, 2014, 22, 272–290.

One of the main objectives of operators and regulators involved in CO₂ geological storage activities is to ensure that the injected CO₂ will remain safely in the underground for a long period of time. Therefore, in addition to the screening and evaluation of the performance of a potential CO₂ storage site, risks of unwanted migration in the subsurface should be addressed and adequately managed. This can include the use of methods to mitigate those risks and ultimately to remediate potential adverse effects. This paper reviews the status of knowledge with regards to the mitigation and remediation technologies, from mature techniques adapted from other fields, such as oil and gas industry and environmental clean-up, to research topics offering potential new possibilities. Several categories can be defined: (1) interventions on operational or decommissioned wells to re-establish their integrity; (2) pressure/fluid management techniques

for countering the leakage driving forces and/or removing the leaking fluids; (3) emerging technologies providing new mitigation opportunities for controlling undesired CO₂ migration; (4) techniques to remediate the impacts potentially induced by such a migration. This technical state of the art is completed by the actual practices in the emerging field of CO₂ geological storage established from the regulatory requirements and guidelines, and from the experience gained in existing storage projects over the world. This article concludes on important best practices stemming from this review and on future challenges in terms of research topics and operational needs.

15/00527 NO₂ concentration analysis in urban area of Catania

Lanzafame, R. *et al. Energy Procedia*, 2014, 45, 671–680.

Recent scientific research has revealed principal causes and trend of nitrogen dioxide (NO₂), a chemical gas harmful for the human respiratory apparatus. The generation of this gas is principally associated with the high temperature combustion processes such as those in internal combustion engines and thermal power plants. In the urban area of Catania there are no thermal power plants so, the most important NO₂ generation is related to the increasing use of vehicles. It is also demonstrated that NO₂ is correlated with other pollutants such as PM₁₀ and PM_{2.5}. The city of Catania is provided by an air quality monitoring network made up of five fixed stations. The principal monitored pollutants are: NO₂, CO, BTX, PM₁₀, O₃ and SO₂. This paper focuses on the analysis of the big amount of NO₂ data recorded by a Philips model 42 instrument in the urban area of Catania. This data has been validated and analysed in order to conduct a multivariate statistical analysis. The principal component analysis and cluster analysis have been developed related to the atmospheric parameters (wind velocity, air temperature, precipitation, relative humidity, global solar radiation) in the period between 2009 and 2012. This multivariate analysis has been applied to the investigation process about the linear dependence of NO₂ to these parameters. Another important aim of this paper has been to study the trend of NO₂ concentration and the number of times this value has overtaken the limits imposed by the Air Quality Directive 2008/50/EC.

15/00528 Research on sulfur recovery from the byproducts of magnesia wet flue gas desulfurization

Yan, L. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 487–494.

To recycle sulfur from by-products of magnesia wet flue gas desulfurization, the authors conducted an experimental study and computational analysis on the factors influencing the SO₂ mole fraction in the calciner gas by an industrial demonstration unit. With a sulfur content of 1.65% in coal and a generating capacity of 300 MW of power plant, the economics of the renewable magnesium oxide desulfurization technology was compared to that of limestone–gypsum desulfurization technology. The results show that the decomposition reaction of byproducts mainly occurred in the lower zone of the furnace. When the excess air coefficient was 1.05 and the magnesium sulfite content in the by-products was 60%, the SO₂ mole fraction in the calciner gas was 10.5%. Decreasing the excess air coefficient can improve the SO₂ mole fraction in the calciner gas. When the moisture content in the byproducts was 15%, the SO₂ mole fraction reached 9.2%. The calciner exit gas temperature should be controlled at 1253.5 K or below. Adopting oxygen-enriched combustion, the oxygen content in air should be controlled to 31%. The magnesium oxide desulfurization renewable technology was found to be more economic.

15/00529 Silicate rock dissolution by ammonium bisulphate for pH swing mineral CO₂ sequestration

Sanna, A. *et al. Fuel Processing Technology*, 2014, 120, 128–135.

A wide range of mineral resources and different technical approaches can be employed to permanently sequester the CO₂ into stable carbonates through mineral carbonation. The aim of this work was to investigate the dissolution and carbonation of olivine, pyroxene and amphibole-rich rocks using an ammonium salt pH swing mineral carbonation process. The effect of temperature (50, 70 and 100 °C) and time (5, 10, 15, 30, 60, 120 and 180 min) and the dissolution kinetics were studied using a batch reactor at ambient pressure. Temperature had a direct effect on the rates of mineral dissolution reactions. The higher dissolution efficiency using olivine with particles 75–150 µm was 77% in 3 h at 100 °C, with a limitation due to product layer diffusion with apparent activation energy of 31 kJ mol⁻¹. The final CO₂ sequestration efficiency using olivine was 70 wt%. Besides, only about 30% of Mg was extracted from pyroxene and amphibole at 100 °C due to polymerization of non-dissolved silica and deposition of sulfate minerals on their surface. Therefore, amphibole and pyroxene-rich rocks do not represent a resource for this process. Ammonia-based mineral carbonation could integrate geological storage where the last is not feasible and where CO₂ emitters and olivine resources are closely co-located.

15/00530 Spatial and temporal variations of particulate matter concentrations in multifamily apartment buildings

Prasauskas, T. *et al. Building and Environment*, 2014, 76, 10–17.

This study reports a comprehensive assessment of particulate matter (PM) concentrations and its variations in multifamily apartment buildings. Fifty apartments in 10 multifamily buildings were investigated during heating seasons of 2011 and 2012 in Kaunas city, Lithuania. PM concentration and size distribution measurements were performed using the optical particle counters indoors and outdoors. Usually mean 24-h indoor PM concentrations were lower (median 7.8 µg/m³ for PM_{2.5}) than outdoor concentrations (median 16.9 µg/m³ for PM_{2.5}) of corresponding location, and I/O ratios of PM_{2.5} were lower (0.70) than that of PM₁₀ (0.98). Night-time levels, representing background indoor exposure to PM, were equal to 5.0 (PM_{2.5}) and 6.7 µg/m³ (PM₁₀), respectively. Particle deposition rates were determined by regression fitting of the measured PM_{2.5} concentration decay curves, with the median equal to 0.32 h⁻¹. The data have been discussed aiming to characterize indoor PM sources and select the most representative indicator(s) for an assessment of the effects of energy saving refurbishment on indoor air quality. It was found that a combination of several indicators allowed an adequate characterization of indoor PM sources and can be used in the subsequent assessment.

15/00531 The use of vacuum ultraviolet irradiation to oxidize SO₂ and NO_x for simultaneous desulfurization and denitrification

Ye, J. *et al. Journal of Hazardous Materials*, 2014, 271, 89–97.

A simple and efficient method for simultaneous desulfurization and denitrification via vacuum ultraviolet (VUV) irradiation and with no additional chemicals is presented. The simultaneous removal of 90% SO₂ and 96% NO_x (NO + NO₂) was achieved from the simulated flue gas under the irradiation from a low-pressure mercury lamp with main wavelengths of 185 and 254 nm, respectively. The composition, flow rate, and temperature of the simulated flue gas, as well as the VUV light intensity, were evaluated as the factors impacting on the efficiency of SO₂ and NO_x removal. The OH, HO₂, O radicals and O₃ produced from the photolysis of H₂O and O₂ were concluded as the major reactive oxygen species that oxidized SO₂ and NO_x. The additional OH and HO₂ radicals generated through the reactions of NO + HO₂ radical and SO₂ + OH/HO₂ radicals improved treatment efficiency, while the oxidation products of NO_x, e.g. NO₂, HNO₂, HNO₃, and HNO₄, consumed massive reactive oxygen species (such as O, OH, and HO₂ radicals) and thereby reducing the removal efficiencies. The main reaction products were characterized as H₂SO₄ and HNO₃ by ion chromatography, which could be used as chemical or fertilizer raw materials.

15/00532 Theoretical and experimental investigation on effect of injection timing on NO_x emission of biodiesel blend

Saravanan, S. *et al. Energy*, 2014, 66, 216–221.

This study explores the possibility of simultaneous reduction of NO_x and smoke of a stationary compression ignition engine fuelled with a biodiesel blend. The fuel injection timing is retarded which resulted in lower NO_x emissions with an increased smoke intensity. NO_x emissions of the biodiesel at the standard and retarded injection timing were predicted with the help of developed correlations and the same was compared with the NO_x emissions experimentally determined. It was observed that the predicted NO_x emissions of biodiesel are comparable with those experimentally determined. Fuel injection pressure was increased at the retarded injection timing and its effect on NO_x and smoke emissions was investigated. It was observed that the increase in smoke intensity resulting from the retarded injection timing was reduced significantly by increasing the fuel injection pressure.

15/00533 Using real options to determine optimal funding strategies for CO₂ capture, transport and storage projects in the European Union

Eckhaue, J. and Herold, J. *Energy Policy*, 2014, 66, 115–134.

Several projects in the European Union (EU) are currently under development to implement the carbon dioxide capture, transport and storage (CCS) technology on a large scale and may be subject to public funding under EU support initiatives. These CCS projects may develop any combination of three types of operating levels: pilot, demonstration and full-scale, representing progressing levels of electric power generation capability. Several projects have commenced at the demonstration level, with full-scale commercial levels planned for approximately 2020. Taking the perspective of a funding agency, a real options framework was employed for determining an optimal project selection and funding strategy for the development of full-scale CCS plants. Specifically, a stochastic dynamic program (SDP) was formulated and solved for obtaining optimal funding solutions in order to achieve at least one successfully operating full-scale CCS plant by a target year. The model demonstrated the improved risk reduction by employing such a multi-stage competition. The model was extended to consider two sensitivities: (1) the flexibility to spend that budget among

the time periods and (2) optimizing the budget, but specifying each time period's allocation *a priori*. State size and runtimes of the SDP model are provided.

15/00534 Wellbore cement fracture evolution at the cement–basalt caprock interface during geologic carbon sequestration

Jung, H. B. *et al. Applied Geochemistry*, 2014, 47, 1–16. Composite Portland cement–basalt caprock cores with fractures, as well as neat Portland cement columns, were prepared to understand the geochemical and geomechanical effects on the integrity of wellbores with defects during geologic carbon sequestration. The samples were reacted with CO₂-saturated groundwater at 50°C and 10 MPa for 3 months under static conditions, while one cement–basalt core was subjected to mechanical stress at 2.7 MPa before the CO₂ reaction. Micro-X-ray diffraction and scanning electron microscopy with energy dispersive X-ray spectroscopy data collected along the cement–basalt interface after 3-month reaction with CO₂-saturated groundwater indicate that carbonation of cement matrix was extensive with the precipitation of calcite, aragonite, and vaterite, whereas the alteration of basalt caprock was minor. X-ray microtomography (XMT) provided three-dimensional (3D) visualization of the opening and interconnection of cement fractures due to mechanical stress. Computational fluid dynamics (CFD) modelling further revealed that this stress led to the increase in fluid flow and hence permeability. After the CO₂-reaction, XMT images displayed that calcium carbonate precipitation occurred extensively within the fractures in the cement matrix, but only partially along the fracture located at the cement–basalt interface. The 3D visualization and CFD modelling also showed that the precipitation of calcium carbonate within the cement fractures after the CO₂-reaction resulted in the disconnection of cement fractures and permeability decrease. The permeability calculated based on CFD modelling was in agreement with the experimentally determined permeability. This study demonstrates that XMT imaging coupled with CFD modelling represent a powerful tool to visualize and quantify fracture evolution and permeability change in geologic materials and to predict their behaviour during geologic carbon sequestration or hydraulic fracturing for shale gas production and enhanced geothermal systems.

Hydrocarbon emissions

15/00535 Black carbon in soils from different land use areas of Shanghai, China: level, sources and relationship with polycyclic aromatic hydrocarbons

Wang, Q. *et al. Applied Geochemistry*, 2014, 47, 36–43. Black carbon (BC) in soils plays a key role of carrying hydrophobic pollutants like polycyclic aromatic hydrocarbons (PAHs). However, little is known about the spatial distribution, sources of BC and its relationship with PAHs in urban soils. The authors studied BC, total organic carbon (TOC) and PAHs concurrently in 77 soils collected from downtown area, suburban and rural area and industrial area of Shanghai, China. BC was determined by both chemical oxidation (dichromate oxidation, BC_{Cr}) and chemo-thermal oxidation (CTO-375, BC_{CTO}). BC sources were identified qualitatively by BC/TOC concentration ratios and BC-cogenerated high molecular weight (HMW) PAH isomer ratios and quantitatively by principal component analysis followed by multiple linear regression (PCA-MLR). Results showed that BC_{Cr} concentration (4.65 g/kg on average) was significantly higher than BC_{CTO} (1.91 g/kg on average) in Shanghai soils. BC_{Cr} concentrations in industrial area were significantly higher than those in other two. Stronger correlation was found between PAHs and TOC, BC_{Cr} than that between PAHs and BC_{CTO}, which indicates the possibility of PAHs being carried by charcoal and other organic matters thus negating its exclusive dependence on soot. Charcoal was therefore suggested to be taken into account in studies of BC and its sorption of PAHs. BC/TOC ratios showed a mixed source of biomass burning and fossil fuel combustion. PCA scores of BC-cogenerated HMW PAHs isomer ratios in potential sources and soil samples clearly demonstrated that sources of BC in urban soils may fall into two categories: coal and biomass combustion, and traffic (oil combustion and tyre wear). PCA-MLR of HMW PAHs concentrations in soil samples indicated that coal and oil combustion had the largest contribution to BC in urban soils while tyre wear and biomass combustion were important in downtown and rural area, respectively, which indicated they were main sources of HMW PAHs and presumably of BC.

15/00536 Concentration and source identification of polycyclic aromatic hydrocarbons (PAHs) in PM₁₀ of urban, industrial and semi-urban areas in Malaysia

Jamhari, A. A. *et al. Atmospheric Environment*, 2014, 86, 16–27.

Particulate matter (PM₁₀) associated with polycyclic aromatic hydrocarbons (PAHs) in ambient air were determined at two sites within the Klang Valley, Kuala Lumpur (urban, KL) and Petaling Jaya (industrial, PJ), and one site outside the Klang Valley, Bangi (semi-urban, BG). This study aimed to determine the concentration and distribution of PAHs in PM₁₀ and the source of origin through principal component analysis (PCA) and diagnostic ratio analysis. This study also assessed the health risk from exposure to airborne BaP_{eq}. PM₁₀ samples were collected on glass fibre filter paper using a high volume sampler (HVS) for 24 h between September 2010 and April 2011. The filter papers with PM₁₀ were extracted using dichloromethane–methanol (3:1), and analysis of 16 USEPA priority PAHs was determined using gas chromatography with mass spectra. Health risk assessment was estimated using toxic equivalency factors (TEFs) and incremental lifetime cancer risk (ILCR) which quantitatively estimate the exposure risk for age specific group. The results showed that the total PAHs concentrations throughout seasonal monsoons for KL, PJ and BG ranged from 1.33 to 2.97, 2.24 to 4.84 and 1.64 to 3.45 ng m⁻³, respectively. More than 80% of total PAHs consisted of five- and six-ring PAHs such as benzo[a]pyrene (BaP), indeno[1,2,3-cd]pyrene (IcP), benzo[b]fluoranthene (BbF), benzo[k]fluoranthene (BkF) and benzo[g,h,i]perylene (BgP). The presence of benzo[g,h,i]perylene (BgP) with high concentration at all locations suggested a source indicator for traffic emission. PCA and diagnostic ratio analysis also suggested substantial contributions from traffic emission with minimal influence from coal combustion and natural gas emissions. The use of total BaP_{eq} concentration provide a better estimation of carcinogenicity activities, where they contributed to more than 50% of the potential health risk. Health risk assessment showed that the estimated incremental lifetime cancer risk from exposure to airborne BaP_{eq} is negligible at all sampling sites for all age specific group.

15/00537 Diurnal and nocturnal measurements of PAH, nitro-PAH, and oxy-PAH compounds in atmospheric particulate matter of a sugar cane burning region

Souza, K. F. *et al. Atmospheric Environment*, 2014, 83, 193–201. Polycyclic aromatic hydrocarbons (PAHs), nitro-PAHs, and oxy-PAHs were studied in the atmospheric particulate matter of a subtropical rural region (São Paulo state, Brazil) affected by emissions from sugar cane burning. Diurnal and nocturnal samples were collected from May to June of 2010. In general, average PAH concentrations were significantly higher at night, suggesting that the compounds were predominantly emitted to the atmosphere during biomass burning (which was mainly performed at night). The maximum average PAH concentration was found for benzo[b]fluoranthene at night (2.9 ± 5.4 ng m⁻³). Among the nitro-PAH compounds, the highest average concentrations were obtained for 9-nitrophenanthrene in diurnal and nocturnal samples (1.5 ± 1.2 and 1.3 ± 2.1 ng m⁻³, respectively). In contrast to the PAH and nitro-PAH compounds, the oxy-PAHs could not be directly associated with sugar cane burning. The most abundant oxy-PAH compound was benzantrone (1.6 ± 1.3 ng m⁻³) at night, followed by 9,10-anthraquinone (1.1 ± 0.9 ng m⁻³) and 9-fluorenone (0.4 ± 0.1 ng m⁻³) during the day. A correlation matrix was used to explore the origins of the different compounds. The data suggested that during the daytime, direct emissions (mainly in vehicle exhaust) contributed to the presence of PAHs, nitro-PAHs, and oxy-PAHs in air. Photochemical production also appeared to be a source of the majority of nitro-PAHs and oxy-PAHs, while photolysis could have contributed to removal of the nitro-PAHs during the daytime. At night, sugar cane burning emissions were the primary source of the PAHs and nitro-PAHs, with additional sources also contributing to the levels of oxy-PAHs in the atmosphere.

15/00538 Human health risk assessment of a landfill based on volatile organic compounds emission, immission and soil gas concentration measurements

Martí, V. *et al. Applied Geochemistry*, 2014, 49, 218–224. A human health risk assessment (HHRA) was required for a closed landfill located in Cerdanyola del Vallès, Barcelona, Spain. The HHRA had two objectives, to evaluate the present risk of the identified receptors in the area and to safely develop the future urban planning of the area, therefore three scenarios for the current situation and four for the future situation were developed. After reviewing the existing data and exploring the needs of information, the assessment in this study was focused on the measurement of volatile organic compounds (VOCs) fluxes from the subsoil (emission from the landfill at five points), concentrations of VOCs in the air (immission in four urban sites) and concentration of VOCs in soil-gas (measurements at 5 m below ground surface outside the landfill at eight sites). Around 70 VOCs were analysed by using multi-sorbent tubes and thermal desorption gas chromatography. The VOCs that were detected and quantified include alkanes, aromatic hydrocarbons, alcohols, ketones, halocarbons, aldehydes, esters, terpenoids, ethers and nitrogenated and sulfur compounds, furans and carboxylic acids. Specific mercury flux measurements were performed in a hot spot by using

carulite tubes, that were also analysed by using thermal decomposition, amalgamation, and atomic absorption spectrophotometry. Results showed average values of volatile emission fluxes ranging from non-detected to $331 \mu\text{g m}^{-2} \text{ day}^{-1}$ (dichlorodifluoromethane). In the case of immission, the concentration of VOCs measured in the air of populated area surrounding the landfill ranged values from non-detected to $42.0 \mu\text{g m}^{-3}$ (acetic acid). The soil-gas measurements in piezometers around the landfill showed individual VOC values with a maximum $830 \mu\text{g m}^{-3}$ for dichlorodifluoromethane. With the obtained fluxes and concentrations in air and soil-gas, US Environmental Protection Agency methodology and modelling was used to evaluate equivalent concentration in the scenarios considered. Toxicity values from IRIS database were used to finally obtain chemical risk indicators. Admissible risk indicators were obtained in all scenarios. The VOCs that contributed more to risk indexes in RH2 were trichloroethylene, trimethylbenzene, chloroform, 1,2-dichloroethane and carbon tetrachloride. The carcinogenic risk in RH7 was linked to the presence of benzene and chloroform. The comparison of the measurements of the present work with other landfills evidence that HHRA in ambient air would be needed in order to perform a correct landfill management.

15/00539 Optimizing catalysis conditions to decrease aromatic hydrocarbons and increase alkanes for improving jet biofuel quality

Cheng, J. *et al. Bioresource Technology*, 2014, 158, 378–382.

To produce quality jet biofuel with a high amount of alkanes and a low amount of aromatic hydrocarbons, two zeolites of HY and HZSM-5 supporting Ni and Mo were used as catalysts to convert soybean oil into jet fuel. Zeolite HY exhibited higher jet range alkane selectivity (40.3%) and lower jet range aromatic hydrocarbon selectivity (23.8%) than zeolite HZSM-5 (13.8% and 58.9%). When reaction temperature increased from 330 to 390°C, yield of jet fuel over Ni–Mo/HY catalyst at 4 MPa hydrogen pressure increased from 0% to 49.1% due to the shift of reaction pathway from oligomerization to cracking reaction. Further increase of reaction temperature from 390 to 410°C resulted in increased yield of jet range aromatic hydrocarbons from 18.7% to 30%, which decreased jet fuel quality. A high yield of jet fuel (48.2%) was obtained at 1 MPa low hydrogen pressure over Ni (8wt%)–Mo (12wt%)/HY catalyst.

15/00540 Optimizing the emission inventory of volatile organic compounds (VOCs) based on network observations

Chen, S.-P. *et al. Atmospheric Environment*, 2014, 84, 1–8.

Hourly observations of 56 non-methane hydrocarbons (NMHCs) performed by a network of photochemical assessment monitoring stations (PAMS) at 11 locations across Taiwan were used to evaluate 56 speciated emissions and the resulting simulations of an air quality model. Based on the PAMS observations at two urban sites, emission modification was made for the 56 PAMS species in the model. To further test the applicability of this emission correction approach, the same modified emissions were subject to seven different meteorological conditions and comparison with observations of all the 11 PAMS sites. Originally there was a minimum of only eight of 56 species showed agreement with observations for the worst of the 11 PAMS sites and 28 of 56 species for the best site. With modified emissions, the number increased to 13–52 species across the 11 PAMS sites, demonstrating that the simple urban based correction procedure has broad applicability. When applying this modification of PAMS emissions to the simulations of other air quality gases, SO_2 and NO_x showed small changes compared with observations (–0.27% and –2.51%, respectively), while total VOC concentrations showed significant changes (+15.28%) as a result of the adjustment in VOC emissions (+26.7%). Although VOCs are the precursor of ozone, the relatively large changes in VOC did not seem to affect ozone formation to the similar extent, only resulting in the changes of average O_3 by 2.9 ppb (+9.41%). It shows that although the emission modification improves individual VOC simulations, the performance in oxidant simulation is still largely unaltered. Although the original US VOC emission profiles can capture the general features of ambient VOCs, further optimization of emissions may still be needed by referencing extensive observations, so that emissions can better fit domestic conditions and accuracy in model simulations can be improved.

15/00541 Phase change of polycyclic aromatic hydrocarbon clusters by mass addition

Chen, D. *et al. Carbon*, 2014, 77, 25–35.

This study reports the first numerical evidence of the phase change of polycyclic aromatic hydrocarbon (PAH) clusters induced by mass addition using molecular dynamics (MD) simulations. It was found that an irregular spherical coronene₅₀ cluster in the liquid phase is transformed to a columnar particle in the solid phase by coalescing with an identical cluster at 455 K. The evolution of the intermolecular energy and the Lindemann index are used to monitor the phase change process. The physical reason behind this transformation is the size-

dependence of the melting point. The authors hypothesize that this transformation is a possible mechanism explaining the transition from liquid-phase coalescence to solid-phase fractal growth of soot particles.

15/00542 Quantification of aldehydes emissions from alternative and renewable aviation fuels using a gas turbine engine

Li, H. *et al. Atmospheric Environment*, 2014, 84, 373–379.

In this research three renewable aviation fuel blends including two hydrotreated ester and fatty acid (HEFA) blends and one fatty acids ethyl ester (FAE) blend with conventional Jet A-1 along with a gas to liquid (GTL) fuel have been tested for their aldehydes emissions on a small gas turbine engine. Three strong ozone formation precursors: formaldehyde, acetaldehyde and acrolein were measured in the exhaust at different operational modes and compared to neat Jet A-1. The aim is to assess the impact of renewable and alternative aviation fuels on aldehydes emissions from aircraft gas turbine engines so as to provide informed knowledge for the future deployment of new fuels in aviation. The results show that formaldehyde was a major aldehyde species emitted with a fraction of around 60% of total measured aldehydes emissions for all fuels. Acrolein was the second major emitted aldehyde species with a fraction of ~30%. Acetaldehyde emissions were very low for all the fuels and below the detection limit of the instrument. The formaldehyde emissions at cold idle were up to two to threefold higher than that at full power. The fractions of formaldehyde were 6–10% and 20% of total hydrocarbon emissions in ppm at idle and full power respectively and doubled on a g kg^{-1} -fuel basis.

15/00543 Seasonal behavior of non-methane hydrocarbons in the firn air at Summit, Greenland

Helmig, D. *et al. Atmospheric Environment*, 2014, 85, 234–246.

Non-methane hydrocarbons (NMHC) were measured in the ambient air and in the snowpack interstitial firn air at ~1 m depth continuously for nearly 2 years at Summit, Greenland from autumn 2008 through to summer 2010. Additionally, five firn air depth profiles were conducted to a depth of 3 m spanning the winter, spring and summer seasons. Here measurements of ethane, ethene, ethyne, propane, propene, *i*-butane, *n*-butane, *i*-pentane, *n*-pentane, and benzene were reported and the seasonal behaviour of these species in the ambient and firn air discussed. The alkanes, ethyne, and benzene in the firn air closely reflect the ambient air concentrations during all the seasons of the year. In spring and summer seasons, ethene and propene were enhanced in the near-surface firn over that in the ambient air, indicating a photochemical production mechanism for these species within the snowpack interstitial air. Evaluation of the NMHC ratios of *i*-butane/*n*-butane, *i*-pentane/*n*-pentane and benzene/ethyne in both ambient and firn air does not provide evidence for chlorine or bromine radical chemistry significantly affecting these gases, except in a few summer samples, where individual data points may suggest bromine oxidation influence.

15/00544 Significance of wet deposition to removal of atmospheric particulate matter and polycyclic aromatic hydrocarbons: a case study in Guangzhou, China

Guo, L.-C. *et al. Atmospheric Environment*, 2014, 83, 136–144.

Rainwater samples were simultaneously collected from three locations in Guangzhou, a mega metropolitan centre in south China, during the entire year of 2010, and analysed for particulate matter (PM), total organic carbon and polycyclic aromatic hydrocarbons (PAHs), with the objectives of assessing the seasonality of washout effects and efficiency for removal of pollutants from the atmosphere by wet deposition. The contents of PM, particulate organic carbon, and dissolved organic carbon were in the ranges of 0.74–420 (average: 8.1 mg L^{-1}), 0.16–40 (average: 1.3 mg L^{-1}), and 0.34–6.9 mg L^{-1} (average: 1.4 mg L^{-1}), respectively. Concentrations of $\Sigma_{15}\text{PAH}$ (sum of the 16 priority PAH compounds defined by the US Environmental Protection Agency minus naphthalene) in wet deposition samples ranged from 39 to 1580 ng L^{-1} with an average of 170 ng L^{-1} . The PAH concentration levels were slightly abated compared to those acquired previously in Guangzhou during the year of 2005, probably indicating a favourable change of energy consumption patterns in the region. There were moderately significant negative correlations between washout ratios and rainfall intensities (0–4.3 mm h^{-1}). The total annual fluxes of wet and dry depositions combined for PM and PAHs in the urban area of Guangzhou were $34 \text{ g m}^{-2} \text{ yr}^{-1}$ and $6.0 \times 10^2 \mu\text{g m}^{-2} \text{ yr}^{-1}$ with 50 and 57% being contributed from wet deposition, respectively. The monthly capacity for removal (CR) of PM and PAHs (calculated as the wet deposition flux dividing the total flux) varied widely with different months, and was lower during the dry weather season (January to March and October to December) than during the wet weather season (April to September). Finally, the air quality index related to PM_{10} was negatively correlated to CR values of PM and PAHs, indicating the need to control the emissions of anthropogenically derived pollutants during the dry weather season.

15/00545 Stabilization of sewage sludge by different biochars towards reducing freely dissolved polycyclic aromatic hydrocarbons (PAHs) content

Oleszczuk, P. *et al. Bioresource Technology*, 2014, 156, 139–145.
The objective of the study was to identify the effect of various biochars on the content of freely dissolved (C_{free}) polycyclic aromatic hydrocarbons (PAHs) in sewage sludge. Apart from the evaluation of biochars obtained from various materials, the study also included the determination of the effects of biochar particle sizes and biochar production temperature on their ability to bind PAHs in sewage sludge. Increase in biochar dose caused a gradual reduction of C_{free} PAHs content, but only up to the biochar dose of 5%. Depending on the kind of initial material from which the biochar was produced, the reduction of C_{free} PAHs content in sewage sludge varied from 17.4% to 58.0%. Both the temperature and the particle size of biochar had an effect on PAH free concentration reduction. Biochars characterized by a low polarity index (O/C or (O + N)/C) reduced the level of C_{free} PAHs better than biochars with a higher polarity index value.

15/00546 VOC emissions from residential combustion of southern and mid-European woods

Evtugina, M. *et al. Atmospheric Environment*, 2014, 83, 90–98.
Emissions of trace gases [CO_2 , CO, total hydrocarbons (THC)] and volatile organic compounds (VOCs) from the combustion of European beech, Pyrenean oak and black poplar in a domestic woodstove and fireplace were studied. These woods are widely used as biofuel in residential combustion in southern and mid-European countries. VOCs in the flue gases were collected in Tedlar bags, concentrated in sorbent tubes and analysed by thermal desorption-gas chromatography-flame ionization detection. CO_2 emissions ranged from 1415 ± 136 to 1879 ± 29 g kg⁻¹ (dry basis). The highest emission factors for CO and THC, 115.8 ± 11.7 and 24.7 ± 6.3 g kg⁻¹ (dry basis), respectively, were obtained during the combustion of black poplar in the fireplace. European beech presented the lowest CO and THC emission factors for both burning appliances. Significant differences in emissions of VOCs were observed among wood species burnt and combustion devices. In general the highest emission factors were obtained from the combustion of Pyrenean oak in the woodstove. Among the VOCs identified, benzene and related compounds were always the most abundant group, followed by oxygenated compounds and aliphatic hydrocarbons. The amount and the composition of emitted VOCs were strongly affected by the wood composition, the type of burning device and operating conditions. Emission data obtained in this work are useful for modelling the impact of residential wood combustion on air quality and tropospheric ozone formation.

Life cycle analysis

15/00547 A decision-making LCA for energy refurbishment of buildings: conditions of comfort

de Larriva, R. A. *et al. Energy and Buildings*, 2014, 70, 333–342.
This paper is focused on providing information to help in decision-making between five different scenarios for energy refurbishment, evaluating the lifecycle of each and also taking into consideration the level of comfort in dwellings. This work centres on one block built in 1983 in which temperatures have been monitored which show that the optimum temperature conditions are not reached for long periods during the year. The current state of the building is referred to as scenario one. Energy consumption is evaluated considering the lifecycle of the components necessary for the refurbishment, their subsequent operation and disposal. All scenarios address the suitability of passive measures or the implementation of active systems in temperate climates under the assumption that comfort in dwellings is achieved. Scenarios two and three are assessed applying insulation and changing the windows. The fourth and fifth implement an alternative solution, a controlled mechanical ventilation based on a typical mild climate cross-ventilation. Evaluation uses two environmental indicators, gross energy requirement (GER) and global warming potential (GWP). It is concluded that scenarios four and five reduce the GER in 4.4% and 9%, respectively, and the GWP in 2.6% and 4.3% compared to the current state.

15/00548 Comparative life cycle assessments: the case of paper and digital media

Bull, J. G. and Kozak, R. A. *Environmental Impact Assessment Review*, 2014, 45, 10–18.
The consumption of the written word is changing, as media transitions from paper products to digital alternatives. This study reviewed the life cycle assessment (LCA) research literature that compared the environmental footprint of digital and paper media. To validate the role of context in influencing LCA results, the authors assessed LCAs

that did not compare paper and print, but focused on a product or component that is part of the information and communication technology (ICT) sector. Using a framework that identifies problems in LCA conduct, the authors assessed whether the comparative LCAs were accurate expressions of the environmental footprints of paper and print. It was hypothesized that the differences between the product systems that produce paper and digital media weaken LCA's ability to compare environmental footprints. It was also hypothesized that the characteristics of ICT as an industrial sector weaken LCA as an environmental assessment methodology. It was found that existing comparative LCAs offered problematic comparisons of paper and digital media for two reasons – the stark material differences between ICT products and paper products, and the unique characteristics of the ICT sector. It is suggested that the context of the ICT sector, best captured by the concept of 'Moore's law', will continuously impede the ability of the LCA methodology to measure ICT products.

15/00549 Energy-economic life cycle assessment (LCA) and greenhouse gas emissions analysis of olive oil production in Iran

Rajaeifar, M. A. *et al. Energy*, 2014, 66, 139–149.
In this study, the energy and economic flows and greenhouse gas (GHG) emissions of olive oil production in Iran were investigated in terms of a life cycle assessment with considering four main stages of agricultural olive production, olive transportation, olive oil extraction and its oil transportation to the customer centres. Data were collected from 150 olive growers in the Guilan province of Iran. Results revealed that the total energy consumption through the olive oil life cycle was 20,344 MJ ha⁻¹ while the mass-based allocation method results indicated that the total energy consumption was 8035 MJ ha⁻¹. The total energy output was estimated as 23,568 MJ ha⁻¹. The total GHG emissions was estimated to 1333 kg ha⁻¹ (CO₂eq) while the mass-based allocation method results indicated that the total GHG emissions was 525 kg ha⁻¹ (CO₂eq). The agricultural production stage ranked the first in GHG emissions among the four stages with the share of 93.81% of total GHG emissions. Results of econometric model estimation revealed that the impact of human labour, farmyard manure and electricity on olive oil yield and the impact of electricity and chemical fertilizers on GHG emissions were significantly positive.

15/00550 Life cycle and cost assessment of mineral carbonation for carbon capture and storage in European power generation

Giannoulakis, S. *et al. International Journal of Greenhouse Gas Control*, 2014, 21, 140–157.

Large-scale greenhouse gas (GHG) emission reductions are crucial for achieving the European goals for climate change mitigation. A frequently discussed option is carbon capture and storage (CCS), where CO₂ emissions from point sources are captured and stored in geologic structures. However, concerns about risks of leakages of CO₂ from geological storage have been raised. These risks could be avoided with *ex situ* mineral carbonation, where the captured CO₂ is stored in an inert and stable solid form after reacting with calcium and magnesium silicates. For a comprehensive assessment of the environmental and economic performance of this CO₂ storage option in fossil-fuelled power generation chains, life cycle assessment (LCA) and levelized cost of electricity (LCoE) calculations are performed. The implementation of CCS using mineral carbonation leads to life cycle GHG emission reductions of 15–64% and LCoE increases of 90–370% on a per kWh_{el} basis compared to a reference power plant without CCS. The life cycle GHG emission reduction achievable with mineral sequestration is less substantial than with geological storage of CO₂ due to significant energy and chemical additives requirements. Accordingly, LCA results for other environmental indicators are worse than those of the reference plant without CCS and the geological CO₂ storage option.

15/00551 Life cycle assessment as a policy-support tool: the case of taxis in the city of Madrid

Vedrenne, M. *et al. Energy Policy*, 2014, 66, 185–197.
This paper examined the potentialities of life cycle assessment as instrument for policy-support. To this respect, the adoption of an initiative within the Madrid Air Quality Plan (AQP) 2011–2015 regarding the substitution of diesel taxis with hybrid, natural gas and liquid petroleum gas alternatives was studied. Four different scenarios were elaborated, a business-as-usual scenario (BAU), the scenario of the AQP, and two extreme-situation scenarios: all-diesel (ADI) and all-ecologic (AEC). Impacts were characterized according to the International Reference Life Cycle Data System (ILCD) methodology, focusing especially on climate change (CC) and photochemical ozone formation (PO). SimaPro 7.3 was used as analysis and inventory-construction tool. The results indicate that the shift to ecologic alternatives reduced impacts, especially those related to CC and PO. For the complete life cycle, reductions of 13% (CC) and 25% (PO) were observed for AQP against BAU (CC: 1365 GgCO₂, PO:

13336 Mg_{NMVO}C). Deeper reductions were observed for AEC (CC: 34%; PO: 59%), while ADI produced slight increases in impacts if against BAU. The analysis of the use-phase revealed that the central and highest speed zones of the city benefit from the adoption of AQP. This is especially evident in zone 7, with reductions of 16% in CC and 31% in PO, respectively, against BAU (CC_{zone1}: 3443 kgCO₂/veh-km, PO_{zone7}: 11.1 kg_{NMVO}C/veh-km).

15/00552 Life-cycle energy and greenhouse gas analysis of three building types in a residential area in Lisbon

Bastos, J. *et al. Energy and Buildings*, 2014, 69, 344–353.

Residential buildings consume a large fraction of energy and thus represent a major opportunity for reducing energy requirements and greenhouse gas (GHG) emissions. This paper presents a life-cycle energy and GHG analysis of three representative residential building types in Lisbon, Portugal. The life-cycle model focused on building construction, retrofit and use phases, applied an econometric model to estimate energy use in Portuguese households, and considered two functional units: per square metre per year and per person per year. Over the buildings' 75-year lifespan, the use phase accounted for most (69–83%) of the primary energy requirements and GHG emissions. Larger buildings have lower life-cycle energy requirements and GHG emissions on a square metre basis. On a per-person basis, however, this pattern is reversed and larger buildings are associated with higher energy requirements and GHG emissions. Due to the considerable variability and uncertainty associated with life-cycle analyses of buildings, the use of both occupancy- and area-based functional units is recommended.

15/00553 The use of artificial neural network to evaluate insulation thickness and life cycle costs: pipe insulation application

Kayfeci, M. *et al. Applied Thermal Engineering*, 2014, 63, (1), 370–378. This paper reports on the use of artificial neural networks (ANNs) to predict insulation thickness and life cycle costs (LCCs) for pipe insulation applications. Data were collected from insulation markets and some data calculated by using LCC analysis. Using the collected data set and LCC analysis results for training, a three-layer feedforward ANN model based on a backpropagation algorithm was developed. This model was used for predicting optimum insulation thickness, total cost, cost saving and payback period. The effects on the predicted parameter of heating degree-days are discussed in detail. The results show that the network yields a maximum correlation coefficient with minimum mean absolute relative error and root mean square error. The developed ANN model has a very practical use of determining the optimum thickness of insulation for any location in the world when just the input parameters of the ANN model are known.

hot summer sub-zones in snow climates. Implications for energy use and carbon emissions are discussed and mitigation/adaptation measures suggested.

15/00555 A dynamic optimization on economic energy efficiency in development: a numerical case of China

Wang, D. *Energy*, 2014, 66, 181–188.

This paper is based on dynamic optimization methodology in order to investigate the economic energy efficiency issues in developing countries. The paper introduces some definitions about energy efficiency both in economics and physics, and establishes a quantitative way for measuring the economic energy efficiency. The linkage between economic energy efficiency, energy consumption and other macroeconomic variables is demonstrated primarily. Using the methodology of dynamic optimization, a maximum problem of economic energy efficiency over time, which is subjected to the extended Solow growth model and instantaneous investment rate, is modelled. In this model, the energy consumption is set as a control variable and the capital is regarded as a state variable. The analytic solutions can be derived and the diagrammatic analysis provides saddle-point equilibrium. A numerical simulation based on China is also presented; meanwhile, the optimal paths of investment and energy consumption can be drawn. The dynamic optimization encourages governments in developing countries to pursue higher economic energy efficiency by controlling the energy consumption and regulating the investment state as it can conserve energy without influencing the achievement of steady state in terms of Solow model. If that, a sustainable development will be achieved.

15/00556 A post-2020 EU energy technology policy: revisiting the strategic energy technology plan

Ruester, S. *et al. Energy Policy*, 2014, 66, 209–217.

With the European Strategic Energy Technology Plan (SET plan) expiring in 2020, the European Union (EU) needs to revisit its energy technology policy for the post-2020 horizon and to establish a policy framework that fosters the achievement of ambitious EU commitments for decarbonization by 2050. This study discusses options for a post-2020 EU energy technology policy, taking account of uncertain technology developments, uncertain carbon prices and the highly competitive global market for energy technologies. A revised SET plan is proposed that enables policy makers to be pro-active in pushing innovation in promising technologies, no matter what policy context will be realized in the future. In particular, a revised SET plan should include a more technology-specific focus, provide the basis for planning and prioritization among decarbonization technologies, and should be based on a comprehensive approach across sectors. Selected technology targets and EU funding of innovation should be in line with the SET plan prioritization.

15/00557 A systems approach to reduce urban rail energy consumption

González-Gil, A. *et al. Energy Conversion and Management*, 2014, 80, 509–524.

There is increasing interest in the potential of urban rail to reduce the impact of metropolitan transportation due to its high capacity, reliability and absence of local emissions. However, in a context characterized by increasing capacity demands and rising energy costs, and where other transport modes are considerably improving their environmental performance, urban rail must minimize its energy use without affecting its service quality. Urban rail energy consumption is defined by a wide range of interdependent factors; therefore, a system wide perspective is required, rather than focusing on energy savings at subsystem level. This paper contributes to the current literature by proposing an holistic approach to reduce the overall energy consumption of urban rail. First, a general description of this transport mode is given, which includes an assessment of its typical energy breakdown. Second, a comprehensive appraisal of the main practices, strategies and technologies currently available to minimize its energy use is provided. These comprise: regenerative braking, energy-efficient driving, traction losses reduction, comfort functions optimization, energy metering, smart power management and renewable energy micro-generation. Finally, a clear, logical methodology is described to optimally define and implement energy saving schemes in urban rail systems. This includes general guidelines for a qualitative assessment and comparison of measures alongside a discussion on the principal interdependencies between them. As a hypothetical example of application, the paper concludes that the energy consumption in existing urban rail systems could be reduced by approximately 25–35% through the implementation of energy-optimized timetables, energy-efficient driving strategies, improved control of comfort functions in vehicles and wayside energy storage devices.

15/00558 An analysis of UK policies for domestic energy reduction using an agent based tool

Lee, T. *et al. Energy Policy*, 2014, 66, 267–279.

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Supplies, policy, economics, forecasts

15/00554 A comparison of global bioclimates in the 20th and 21st centuries and building energy consumption implications

Li, D. H. W. *et al. Building and Environment*, 2014, 75, 236–249.

Summer and winter thermal discomforts in the major climate zones and sub-zones of the Köppen–Geiger world climate classifications during the twenty-first century were investigated and compared with those in the twentieth century. Compared with the twentieth century, frequency of distribution of the comfort index for the twenty-first century shows a distinct decrease in winter thermal discomfort and increase in summer thermal discomfort under the low and medium forcing emissions scenarios. Based on zone-average analysis, decreasing trends of cumulative cold stress and increasing trends of cumulative heat stress have been observed in all the major climate zones and sub-zones. There is an overall increase in energy use for space conditioning for all the sub-zones in equatorial climates, and an overall reduction in all the snow and polar climates sub-zones. In arid and warm temperate climates, the hot sub-zones have an increase in the overall energy requirements whereas the cold/warm sub-zones have a reduction. Locations within the hot summer sub-zones in warm temperate climates will become much more cooling-dominated, and there are significant increases in cumulative heat and proportional stresses in the

This paper introduces a new agent-based model, which incorporates the actions of individual homeowners in a long-term domestic stock model, and details how it was applied in energy policy analysis. The results indicate that current policies are likely to fall significantly short of the 80% target and suggest that current subsidy levels need re-examining. In the model, current subsidy levels appear to offer too much support to some technologies, which in turn leads to the suppression of other technologies that have a greater energy saving potential. The model can be used by policy makers to develop further scenarios to find alternative, more effective, sets of policy measures. The model is currently limited to the owner-occupied stock in England, although it can be expanded, subject to the availability of data.

15/00559 An integrated approach for an historical buildings energy analysis in a smart cities perspective

De Lieto Vollaro, R. *et al. Energy Procedia*, 2014, 45, 372–378.

Currently, the study of the energy performance of buildings is based on a simplified calculation that estimates the thermal loads using monthly or seasonal average outdoor temperatures. In addition, the employed software require technical data such as the specific heat capacity of materials, but at the same time they are not able to properly consider the thermal inertia of buildings. The more precise evaluation allows one to assess the correct interventions for energy requalification under a smart cities perspective. This study was performed considering a stationary software (Aermec MC11300) and a dynamic software (TRNSYS). Three simulations considering transparent elements characterized by progressively improved properties of thermal transmittance and solar gain factor have been performed. It has been performed a comparison between the outputs of the two software in order to highlight the different ways of evaluating the energy contributions on thermal loads. Finally, the models were validated by means of an in-situ measurement campaign using a heat flow meter – in order to measure the thermal transmittance of the opaque walls – and a thermographic camera. This modus operandi allowed to appreciate how the use of a dynamic software is more appropriate to deal with the inertial properties of the structure to calculate in a more detailed way the annual thermal loads and to obtain more information on individual heating zones.

15/00560 Assessing internet energy intensity: a review of methods and results

Coroama, V. C. and Hilty, L. M. *Environmental Impact Assessment Review*, 2014, 45, 63–68.

Assessing the average energy intensity of Internet transmissions is a complex task that has been a controversial subject of discussion. Estimates published over the last decade diverge by up to four orders of magnitude – from 0.0064 to 136 kWh/GB. This paper presents a review of the methodological approaches used so far in such assessments: (i) top-down analyses based on estimates of the overall Internet energy consumption and the overall Internet traffic, whereby average energy intensity is calculated by dividing energy by traffic for a given period of time, (ii) model-based approaches that model all components needed to sustain an amount of Internet traffic, and (iii) bottom-up approaches based on case studies and generalization of the results. The analysis of the existing studies shows that the large spread of results is mainly caused by two factors: (a) the year of reference of the analysis, which has significant influence due to efficiency gains in electronic equipment, and (b) whether end devices such as personal computers or servers are included within the system boundary or not. For an overall assessment of the energy needed to perform a specific task involving the Internet, it is necessary to account for the types of end devices needed for the task, while the energy needed for data transmission can be added based on a generic estimate of Internet energy intensity for a given year. Separating the Internet as a data transmission system from the end devices leads to more accurate models and to results that are more informative for decision makers, because end devices and the networking equipment of the Internet usually belong to different spheres of control.

15/00561 Asymmetries in the dynamic interrelationship between energy consumption and economic growth: evidence from Turkey

Araç, A. and Hasanov, M. *Energy Economics*, 2014, 44, 259–269.

This study examines the possible non-linearities in dynamic interrelationship between energy consumption and economic growth in Turkey for the 1960–2010 period by using a smooth transition vector autoregressive model. In order to trace the effects of one variable on another, generalized impulse response functions were calculated. The computed impulse response functions demonstrate asymmetric effects of positive versus negative and small versus large energy consumption shocks on output growth and vice versa. Specifically, it was found that negative energy shocks have a greater effect on output growth than positive energy shocks, and that big negative energy shocks affect output much more than small negative energy shocks. Similarly, it was found that positive output shock has a greater effect on energy

consumption whereas negative shocks have almost no effect on energy consumption. The results of this study have clear and important implications for energy economists and policymakers in Turkey.

15/00562 Energy consumption and economic growth in the next 11 countries: the bootstrapped autoregressive metric causality approach

Yildirim, E. *et al. Energy Economics*, 2014, 44, 14–21.

This study analyses the causal relation between economic growth and energy consumption in the Next Eleven countries (Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Turkey, South Korea and Vietnam). Estimating a trivariate model consisting of gross domestic product per capita, energy consumption per capita and gross capital formation, it was found that the neutrality hypothesis is valid for all of the countries except for Turkey. These findings imply that energy conservation-oriented policies should be implemented in Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Pakistan and Philippines. In the case of Turkey, a unidirectional causal nexus was found from energy consumption to economic growth. Since the growth hypothesis is valid, energy conservation policy poses an obstacle for economic growth in Turkey.

15/00563 Energy security and climate change: how oil endowment influences alternative vehicle innovation

Kim, J. E. *Energy Policy*, 2014, 66, 400–410.

Fast growing global energy needs raise concerns on energy supply security and climate change. Although policies addressing the two issues sometimes benefit one at the expense of the other, technology innovation, especially in alternative energy, provides a win-win solution to tackle both issues. This paper examines the effect of oil endowment on the patterns of technology innovation in the transportation sector, attempting to identify drivers of technology innovation in alternative energy. The analysis employs panel data constructed from patent data on five different types of automobile-related technologies from 1990 to 2002: oil extraction, petroleum refining, fuel cells, electric and hybrid vehicles and vehicle energy efficiency. It was found that countries with larger oil endowments perform less innovation on refining and alternative technologies. Conversely, higher gasoline prices positively impact the patent counts of alternative technologies and energy efficiency technology. The findings highlight the challenges and importance of policy designs in international climate change agreements.

15/00564 Energy security in China: a quantitative analysis and policy implications

Yao, L. and Chang, Y. *Energy Policy*, 2014, 67, 595–604.

This study aims to examine how China's energy security has changed over 30 years of reform and the opening period. It constructs a four 'A's' quantitative evaluation framework: the availability of energy resources, the applicability of technology, the acceptability by society and the affordability of energy resources. The quantitative results show that China's energy security was at its best during the sixth five-year plan period (1981–1985), but then deteriorated until it hit higher levels between 1995 and 2005. However, it was still lower than the level reached during the sixth five-year period. During the eleventh five-year plan period (2006–2010), the energy security situation deteriorated again. Differences in policy priority over the study period appear to affect the country's energy security status. This study suggests that China needs to develop renewable energy resources on a large scale and pay more attention to emissions control to reverse the downward trend in energy security.

15/00565 Energy-growth conundrum in energy exporting and importing countries: evidence from heterogeneous panel methods robust to cross-sectional dependence

Jalil, A. *Energy Economics*, 2014, 44, 314–324.

This paper uses the panel methods for energy exporting and importing countries that discuss the heterogeneity and cross-sectional dependence in investigating the linkages between energy consumption and economic growth. The findings of the study suggest that the energy consumption is an important input not only in the energy importing but also in energy exporting countries. Furthermore, the results of the study suggest that the policy options should be different for the different countries in the back drop of heterogeneous slope coefficients.

15/00566 Enhanced understanding of energy ratepayers: factors influencing perceptions of government energy efficiency subsidies and utility alternative energy use

Craig, C. A. and Allen, M. W. *Energy Policy*, 2014, 66, 224–233.

This study explores factors related to energy consumers' perceptions of government subsidies for utility provided energy efficiency (EE) programmes and for utility providers' use of more clean/alternative energy sources. Demographic factors, attitudes, planned purchases, and perceptions of utility provider motives in relation to governmental

and utility provider EE initiatives (i.e. providing discounts and coupons for energy-saving light bulbs), plus the influence of gain- and loss-framed messages are investigated. Over 2000 respondents completed a 16-item phone survey. Hierarchical regression explained 38% of the variance in reactions regarding government subsidies of the cost of utility provided EE programs and 43% of the variance in perceptions involving whether utility companies should use of more clean or alternative forms of energy. Gender and party differences emerged. Loss-framed messages were more important when the issue was government subsidies. Both gain- and loss-framed messages were important when clean/alternative energy was the issue.

15/00567 Exceeding the Ontario Building Code for low-rise residential buildings: economic and environmental implications

Di Placido, A. M. *et al. Building and Environment*, 2014, 77, 40–49.

The residential sector accounts for approximately one-fifth of Canada's secondary energy use and greenhouse gas emissions. Thus, addressing the energy efficiency of residential buildings has a significant role to play in reducing the nation's overall greenhouse gas emissions. The Ontario Building Code has recently been updated to reflect a more stringent energy performance standard. A home built to the prescribed minimum requirements will perform at a relatively high standard with respect to energy use when compared to homes built less than a decade ago. This paper explores three energy efficiency upgrade options which improve upon the energy efficiency of the 2012 Ontario Building Code. The 'controlled ventilation' upgrade involved tightening up the building envelope and adding heat recovery to waste air streams, and two additional upgrade options were developed to meet the high performance targets of the R-2000 standard. While the upgrades explored did not show financial benefit for individual homeowners at current utility rates, if the benefits to society are considered, the upgrades are an economically efficient method of reducing greenhouse gas emissions owed to energy consumption. In addition to highlighting the need for a broader approach to the cost-benefit analyses associated with these types of upgrades, this finding also warrants a discussion about how to transform the current housing market so that energy efficient homes are more appropriately valued.

15/00568 Exploring public perceptions of energy security risks in the UK

Demski, C. *et al. Energy Policy*, 2014, 66, 369–378.

Along with climate change and affordability, concerns about energy security are key drivers behind proposals for major energy system change in the UK and numerous other countries. Unlike climate change, very little is known about how the public thinks and feels about this aspect of sustainability and energy policy. Beyond engaging critically with conceptual and theoretical discussions, empirical data from two surveys (Cardiff postal survey, $N = 520$; online UK survey, $N = 499$) using a 10-item energy security scale are presented and discussed. Here aspects of energy security are shown to be of concern to the UK public, with particularly high concern around dependence on fossil fuels/imports and relatively lower expressed concern for actual disruption of energy supply. However public concerns around energy security are only emerging, and likely to change depending on the context in which it is discussed (e.g. in comparison to climate change). In addition, findings from public interviews are used to further contextualize the survey findings, showing unfamiliarity among the UK public with regards to the term 'energy security'. Implications, as well as further work that would be useful for understanding public perceptions in more depth, are also discussed.

15/00569 Forecasting energy markets using support vector machines

Papadimitriou, T. *et al. Energy Economics*, 2014, 44, 135–142.

This study investigates the efficiency of a support vector machine (SVM)-based forecasting model for the next-day directional change of electricity prices. First, it was adjusted to the best autoregressive SVM model and then enhanced with various related variables. The system was tested on the daily Phelix index of the German and Austrian control area of the European Energy Exchange (EEX) wholesale electricity market. The forecast accuracy achieved was 76.12% over a 200-day period.

15/00570 Fuelling expectations: a policy-promise lock-in of UK biofuel policy

Berti, P. and Levidow, L. *Energy Policy*, 2014, 66, 135–143.

Controversy over European Union (EU)-wide biofuel policy resonated within the UK, fuelling policy disagreements among UK public authorities. They disagreed over how to protect a space for future second-generation biofuels, which were expected to overcome harm from first-generation biofuels. The UK government defended rising targets for available biofuels as a necessary stimulus for industry to help fulfil the UK's EU obligations and eventually develop second-generation biofuels. By contrast, Parliamentary Select Committees

opposed biofuel targets on grounds that these would instead lock-in first-generation biofuels, thus delaying or pre-empting second-generation biofuels. Those disagreements can be explained by different institutional responsibilities and reputational stakes towards 'promise-requirement cycles', whereby techno-optimistic promises generate future requirements for the actors involved. The UK government's stance illustrates a 'policy-promise lock-in', a dilemma whereby promised support is a requirement for credibility towards technology innovators and thus technoscientific development – but may delay the redirection of support from incumbent to preferable emerging technologies. Thus the sociology of expectations – previously applied to technological expectations from technology innovators – can be extended to analyse public authorities.

15/00571 He who has the pipeline calls the tune? Russia's energy power against the background of the shale 'revolutions'

Kropatcheva, E. *Energy Policy*, 2014, 66, 1–10.

Russian energy policy is usually considered in the regional context – in terms of its energy power capability and strength *vis-à-vis* the European Union (EU) and the post-Soviet states. This study shows that in order to understand Russia's energy power, even in the regional context of its relations with the EU, it is necessary to consider the impact of international changes in the energy sector. The oil and gas shale 'revolutions' represent such a global factor of influence. Even if their consequences are not yet clear, they have already become an important challenge for Russian energy policy and power. This policy-oriented article, guided by neoclassical realism, analyses what the shale 'revolutions' mean for Russia's energy policy and its power capabilities *vis-à-vis* the EU, how the Russian political elite perceive this development and how Russia reacts to it. In this context, Russian power capabilities look more moderate.

15/00572 Long-term climate policy implications of phasing out fossil fuel subsidies

Shwanitz, V. J. *et al. Energy Policy*, 2014, 67, 882–894.

It is often argued that fossil fuel subsidies hamper the transition towards a sustainable energy supply as they incentivize wasteful consumption. The implications of a subsidy phase-out for the mitigation of climate change and the low-carbon transformation of the energy system were assessed using the global energy-economy model REMIND. This study compared these results with those obtained by the International Energy Agency (based on the World Energy Model) and by the Organization for Economic Co-Operation and Development (OECD-Model ENV-Linkages), providing the long-term perspective of an intertemporal optimization model. The results were analysed in the two dimensions of subsidy phase-out and climate policy scenarios. The short-term benefits of phasing-out fossil fuel subsidies, as found in prior studies, were confirmed. However, these benefits are only sustained to a small extent in the long term, if dedicated climate policies are weak or non-existent. Most remarkably it was found that a removal of fossil fuel subsidies, if not complemented by other policies, can slow down a global transition towards a renewable-based energy system. The reason is that world market prices for fossil fuels may drop due to a removal of subsidies. Thus, low carbon alternatives would encounter comparative disadvantages.

15/00573 Long-term transport energy demand and climate policy: alternative visions on transport decarbonization in energy-economy models

Pietzcker, R. C. *et al. Energy*, 2014, 64, 95–108.

Decarbonizing transport will be necessary to limit global warming below 2°C. Due to persistent reliance on fossil fuels, it is posited that transport is more difficult to decarbonize than other sectors. To test this hypothesis, the authors compare long-term transport energy demand and emission projections for China, USA and the world from five large-scale energy-economy models. The authors diagnose the model's characteristics by subjecting them to three climate policies. They systematically analyse mitigation levers along the chain of causality from mobility to emissions, finding that some models lack relevant mitigation options. It is partially confirmed that transport is less reactive to a given carbon tax than the non-transport sectors: in the first half of the century, transport mitigation is delayed by 10–30 years compared to non-transport mitigation. At high carbon prices towards the end of the century, however, the three global models achieve deep transport emission reductions by >90% through the use of advanced vehicle technologies and low-carbon primary energy; especially biomass with carbon dioxide capture and sequestration plays a crucial role. The extent to which earlier mitigation is possible strongly depends on implemented technologies and model structure. Compared to the global models, the two partial-equilibrium models are less flexible in their reaction to climate policies.

15/00574 Managing energy Smart Homes according to energy prices: analysis of a building energy management system

Missaoui, R. *et al. Energy and Buildings*, 2014, 71, 155–167.
The demand-side-load management will change the way people behave. Different authors have proposed energy management algorithms for Smart Home that either integrates or not renewable energy. All these researches have the same general objective: minimizing the daily energy cost without affecting the comfort of occupants. This paper deals with the performance analysis of a global model based anticipative building energy management system (GMBA-BEMS) managing household energy. This GMBA-BEMS is able to optimize a compromise between user comfort and energy cost taking into account occupant expectations and physical constraints like energy price and power limitations. To validate the GMBA-BEMS, the model of a building has been developed in MATLAB/Simulink. This work analyses the GMBA-BEMS application that manages appliances such as heating, washing machine and dishwasher from a grid point of view.

15/00575 MES (multi-energy systems): an overview of concepts and evaluation models

Mancarella, P. *Energy*, 2014, 65, 1–17.
Multi-energy systems (MES) whereby electricity, heat, cooling, fuels, transport, and so on optimally interact with each other at various levels (for instance, within a district, city or region) represent an important opportunity to increase technical, economic and environmental performance relative to 'classical' energy systems whose sectors are treated 'separately' or 'independently'. This performance improvement can take place at both the operational and the planning stage. While such systems and in particular systems with distributed generation of multiple energy vectors (distributed multi-generation, DMG) can be a key option to decarbonize the energy sector, the approaches needed to model and relevant tools to analyse them are often of great complexity. Likewise, it is not straightforward to identify performance metrics that are capable to properly capture costs and benefits that are relating to various types of MES according to different criteria. The aim of this paper is thus to provide the reader with a comprehensive and critical overview of the latest models and assessment techniques that are currently available to analyse MES and in particular DMG systems, including for instance concepts such as energy hubs, microgrids, and virtual power plants, as well as various approaches and criteria for energy, environmental, and techno-economic assessment.

15/00576 Multi-perspective analysis of China's energy supply security

Geng, J.-B. and Ji, Q. *Energy*, 2014, 64, 541–550.
China's energy supply security has faced many challenges, such as the drastic change of the international energy environment and the domestic energy situation and so on. This paper constructs a multi-dimensional indicator system for the main risks deriving from four aspects to evaluate the situation of China's energy supply security and analyse its evolution characteristics from 1994 to 2011. The results indicate that the situation of China's energy supply security generally presented a downtrend during 1994–2008, as a result of increasing international energy market monopoly and high volatility of international crude oil prices. After 2008, the overall level of China's energy supply security has improved to the level of 2003, which is attributed to the relatively stable international energy environment as well as the effective implementation of energy policies.

15/00577 Oxyfiring with CO₂ capture to meet low-carbon fuel standards for unconventional fuels from Utah

Kelly, K. E. *et al. International Journal of Greenhouse Gas Control*, 2014, 22, 189–199.

The transportation fuel sector is under pressure to reduce its greenhouse gas (GHG) emissions as a result of low-carbon fuel standards (LCFSs), which have been passed by the State of California and the European Union. These standards will be particularly challenging for producers of oil sands, heavy oil, and other unconventional resources. Oxyfiring with CO₂ capture is a promising technology for reducing CO₂ emissions from the transportation fuel sector, but it requires a significant amount of energy to generate oxygen. This study examines the potential for oxyfiring to reduce life-cycle GHG emissions from transportation fuels derived from *in situ* and *ex situ* oil shale and *ex situ* oil sands in the Uinta Basin of Utah. It also examines the effect of oxyfiring with CO₂ capture on the net energy return. The evaluation focuses on the fuel's life-cycle GHG emissions, and it includes resource extraction, upgrading, transportation and refining. The results suggest that oxyfiring could help some unconventional sources of crude oil, such as *ex situ* production of oil sands and oil shale, meet a LCFS. However, oxyfiring with CO₂ capture reduces net energy return.

15/00578 Performance indexes and output allocation for multi-fuel energy systems

Bianchi, M. *et al. Energy Procedia*, 2014, 45, 32–41.
This paper takes into account the concept of conversion efficiency by exploring multi-fuel (MF) energy systems. A MF system can be defined as a system with various fuel energy input and useful product output. The difficult task in defining a performance index for MF systems consists in quantifying the contribution of each input fuel to the total output energy. This paper intends to make few proposals and start a discussion that would be helpful to assess the MF system performance. The conventional first law efficiency, normally used to assess performance of single-fuel (SF) system, can be applied but it provides incomplete information for a MF system. The electric equivalent efficiency, the relative and overall MF synergy index concepts are introduced as most significant performance indexes; these new performance indexes are presented with the aim to evaluate the MF performance compared to reference SF scenarios. Proposed performance indexes are analysed, discussed and compared from a general point of view, identifying aspects of relation and main differences. The introduced conversion efficiency indexes are applied and discussed to a specific co-combustion power plant case. The influence of the reference scenarios, as it is highlighted in the paper, results of key importance. The evaluation of the proposed indexes is of relevant interest with the goal of formulating a specific and unified theory about MF power energy systems.

15/00579 Policy implications for improved cook stove programs – a case study of the importance of village fuel use variations

Vahlne, N. and Ahlgren, E. O. *Energy Policy*, 2014, 66, 484–495.
Despite the long history of cook stove programmes, very few have been successful, often only in areas where biomass is purchased or there is a biomass shortage. Several studies have described how rural households generally rely on several different fuels; which fuels are used may depend on various household characteristics such as location and income. This article explores possible consequences of variations in fuel usage for improved cook stove programmes and how this may vary between different areas. Reductions of CO₂ equivalent emissions and monetary savings are calculated for hypothetical cook stove deployment using data from a rural energy survey in the Vinh Phúc province of northern Vietnam. The results indicate that the areas may respond differently to the various stove options, both in terms of economy and emission reductions. Furthermore, there are large differences in emission reduction calculations when only Kyoto-gases are included and when non-Kyoto greenhouse agents are added. Assumptions regarding household behaviour and stove efficiencies have large impacts on the results, indicating a need for further research on how improved cook stoves may influence households' fuel choices.

15/00580 Production and use of electrolytic hydrogen in Ecuador towards a low carbon economy

Pelaez-Samaniego, M. R. *et al. Energy*, 2014, 64, 626–631.
This paper presents a pre-feasibility study of producing and using electrolytic hydrogen in Ecuador as part of a strategy towards a low carbon economy. Hydrogen could be produced using hydropower either alone or combined with other renewable energy sources. This study analysed two scenarios of energy availability based on data from the largest hydroelectric power plant in the country. The first scenario assumes that an amount of water equivalent to 30% of that spilled in 2011 could be used to generate additional electricity. Thus, an additional amount of energy equivalent to 5% of the energy produced in 2011 could be available. The second scenario doubles this amount of energy. Economic analysis showed that to obtain low-cost hydrogen (US\$3.00/kg) it is necessary to operate the electrolysis plants 24 h/day, using low-cost electricity (\$30/MWh). A continuous supply of energy could be possible when new hydroelectric utilities start operating or by integrating hydropower with solar and wind. Three possibilities for using hydrogen are discussed: (1) production of ammonia as a raw material for nitrogenous fertilizers, (2) hydro-treating heavy oils and bio-oils in oil refineries, and (3) as an energy storage medium to offset natural instability and unpredictability of renewables.

15/00581 Quantification of environmental and economic impacts for main categories of building labeling schemes

Seinre, E. *et al. Energy and Buildings*, 2014, 70, 145–158.
This study evaluated the weighting factors of five building sustainability assessment scheme categories – productivity, energy, water, materials and transport – to be used in Estonia. The method was based on environmental and economic assessment of available design options relevant for each category and transferring all impacts to Euros through energy and carbon prices and productivity costs. The productivity category received the highest weighting, 89% or 70% share of the total impact with indoor climate reference class III and class II, respectively. This shows that the productivity effects are not enough recognized in current codes. To assign meaningful weightings

for other categories the share of productivity was limited to 50%. The final weightings obtained with Estonian input data were 50% for productivity, 26% for energy, 21% for location, 2% for building materials and 1% for water efficiency. Obtained weighting factors for Estonia conflict quite remarkably with the weights of most well-known building sustainability assessment schemes, BREEAM and LEED, showing the importance of local conditions. Results denote that specific CO₂ emissions of energy sources change the importance of categories considerably. All findings in this study show that local context should be considered when designing a building sustainability assessment scheme.

15/00582 Renewable and non-renewable energy consumption and economic activities: further evidence from OECD countries

Salim, R. A. *et al. Energy Economics*, 2014, 44, 350–360.

This paper examines the dynamic relationship between renewable and non-renewable energy consumption and industrial output and gross domestic product (GDP) growth in Organization for Economic Co-operation and Development (OECD) countries using data over the period of 1980–2011. The panel cointegration technique allowing structural breaks is used for empirical investigation. The results show that there is a long-term equilibrium relationship among non-renewable and renewable energy sources, industrial output and economic growth. The panel causality analyses show bidirectional causality between industrial output and both renewable and non-renewable energy consumption in the short and long run. However, there is evidence of bidirectional short-run relationship between GDP growth and non-renewable energy consumption while unidirectional causality between GDP growth and renewable energy consumption. These results indicate that OECD economies still remain energy-dependent for their industrial output as well as overall economic growth. However, expansion of renewable energy sources is a viable solution for addressing energy security and climate change issues, and gradually substituting renewable to non-renewable energy sources could enhance a sustainable energy economy.

15/00583 Road grade quantification based on global positioning system data obtained from real-world vehicle fuel use and emissions measurements

Boroujeni, B. Y. and Frey, H. C. *Atmospheric Environment*, 2014, 85, 179–186.

Real-world vehicle fuel use and emission rates depend on engine load, which is quantified in terms of vehicle specific power (VSP). VSP depends on vehicle speed, acceleration, and road grade. There is not a standard method for measuring road grade from a moving vehicle. A method for quantifying grade is evaluated based on statistical analysis of multiple runs using low cost consumer-grade global positioning system (GPS) receivers with in-built barometric altimeter (GPS/BA). The average grade precision is ± 0.71 , ± 0.46 , and ± 0.31 percentage points, for sample sizes of 9, 18 and 36 GPS/BA runs, respectively, among 2213 individual 0.08 km road segments. In addition, four sets of repeated measurements were performed on the same routes using a high cost, high accuracy differential GPS (DGPS). Both sets of GPS-based grade estimates compared well with those derived from light detection and ranging (LIDAR) data. GPS/BA and DGPS grade estimates were similar, except for high magnitude grades of 8–10% for which DGPS estimates are more accurate. DGPS is more sensitive to loss of signal; thus, a hybrid approach for substituting GPS/BA data for missing DGPS data at specific locations along a route is demonstrated. The local and overall effects of road grade on fuel use and emission rates are investigated for an example light duty gasoline vehicle.

15/00584 The influence of the Energy Performance Certificate: the Dutch case

Murphy, L. *Energy Policy*, 2014, 67, 664–672.

All European Union member states require an Energy Performance Certificate (EPC) when buildings are constructed, sold and rented. At its introduction, the EPC was considered a pioneering instrument, one that would help overcome an information deficit hindering consumer interest in energy efficient dwellings. Now that the EPC has been implemented for several years it is possible to examine its impact. This research draws on data from *ex ante* and *ex post* assessments of the EPC in a number of countries and presents the results of a survey of Dutch private dwelling purchasers. This survey was based on two sample populations, one received an EPC during property transaction and another did not. Differences were sought between the two samples in a number of areas relating to the adoption of energy efficiency measures. Results show that many projections about the impact of the EPC have fallen short. The EPC was found to have a weak influence, especially pre-purchase. The potential of the EPC in driving energy efficiency improvement in the existing stock is doubtful, especially if it continues to act independently from a mix of instruments designed to

tackle multiple barriers. It is argued that the energy-saving potential of existing dwellings, applauded in climate change policy, will remain unexploited if it continues to be assessed subjectively by householders.

15/00585 The past, present and future of carbon labelling for construction materials – a review

Wu, P. *et al. Building and Environment*, 2014, 77, 160–168.

Global climate change is one of the most significant environmental issues that can harm human development. One central issue for the building and construction industry to address global climate change is the development of a credible and meaningful way to measure greenhouse gas (GHG) emissions. While Publicly Available Specification (PAS) 2050, the first international GHG standard, has been proven to be successful in standardizing the quantification process, its contribution to the management of carbon labels for construction materials is limited. With the recent publication of ISO 14067: 'Greenhouse gases – carbon footprint of products – requirements and guidelines for quantification and communication' in May 2013, it is necessary for the building and construction industry to understand the past, present and future of the carbon labelling practices for construction materials. A systematic review shows that international GHG standards have been evolving in terms of providing additional guidance on communication and comparison, as well as less flexibility on the use of carbon labels. At the same time, carbon labelling schemes have been evolving on standardization and benchmarking. In addition, future actions are needed in the aspect of raising consumer awareness, providing benchmarking, ensuring standardization and developing simulation technologies in order for carbon labelling schemes for construction materials to provide credible, accurate and transparent information on GHG emissions.

15/00586 The relationship among oil, natural gas and coal consumption and economic growth in BRICs (Brazil, Russian, India, China, Turkey and South Africa) countries

Bildirici, M. E. and Bakirtas, T. *Energy*, 2014, 65, 134–144.

The causality relationship between economic growth and coal, natural gas and oil consumption was investigated using the autoregressive distributed lag bounds testing approach for the 1980–2011 period in Brazil, Russian, India, China, Turkey and South Africa. According to long-run and strong causality results, there is bi-directional causality between oil energy consumption and Y for all countries. The long-run causality and strong causality results between coal consumption and economic growth indicated that there is bi-directional causality for China and India. According to long-run causality results and a strong causality result, there are bi-directional causality relationships between natural gas energy consumption and Y for Brazil, Russia and Turkey.

15/00587 Volatility in federal funding of energy R&D

Schuelke-Leech, B.-A. *Energy Policy*, 2014, 67, 943–950.

Funding for research and development (R&D) in any given industry or technology is considered essential to its ongoing competitiveness and longevity. This paper analyses the allocation of federal R&D funding for energy between 2000 and 2012. The results show that funding for energy R&D is very volatile for both the aggregate energy research types, such as coal or nuclear power, and specific research areas, such as carbon capture and sequestration or nuclear waste reprocessing. While overall funding levels are often sources of frustration, budgetary volatility may be as much of a problem.

Energy conservation

15/00588 A bottom-up energy analysis across a diverse urban building portfolio: retrofits for the buildings at the Royal Botanic Gardens, Kew, UK

Ward, R. M. and Choudhary, R. *Building and Environment*, 2014, 74, 132–148.

A methodology for the analysis of building energy retrofits has been developed for a diverse set of buildings at the Royal Botanic Gardens (RBG), Kew in southwest London, UK. The methodology requires selection of appropriate building simulation tools dependent on the nature of the principal energy demand. This has involved the development of a stand-alone model to simulate the heat flow in botanical glasshouses, as well as stochastic simulation of electricity demand for buildings with high equipment density and occupancy-led operation. Application of the methodology to the buildings at RBG Kew illustrates the potential reduction in energy consumption at the building scale achievable from the application of retrofit measures deemed appropriate for heritage buildings and the potential benefit to be gained from onsite generation and supply of energy.

15/00589 A comprehensive framework to quantify energy savings potential from improved operations of commercial building stocks

Azar, E. and Menassa, C. C. *Energy Policy*, 2014, 67, 459–472. While studies highlight the significant impact of actions performed by occupants and facility managers on building energy performance, current policies ignore the importance of human actions and the potential energy savings from a more efficient operation of building systems. This is mainly attributed to the lack of methods that evaluate non-technological drivers of energy use for large stocks of commercial buildings to support policy making efforts. Therefore, this study proposes a scientific approach to quantifying the energy savings potential due to improved operations of any stock of commercial buildings. The proposed framework combines energy modelling techniques, studies on human actions in buildings, and surveying and sampling methods. The contributions of this study to energy policy are significant as they reinforce the role of human actions in energy conservation, and support efforts to integrate operation-focused solutions in energy conservation policy frameworks. The framework's capabilities are illustrated in a case study performed on the stock of office buildings in the USA. Results indicate a potential 21% reduction in the current energy use levels of these buildings through realistic changes in current building operation patterns.

15/00590 A hybrid method of incorporating extended priority list into equal incremental principle for energy-saving generation dispatch of thermal power systems

Cheng, C. *et al. Energy*, 2014, 64, 688–696. The energy-saving generation dispatch (ESGD) policy released by the Chinese government in 2007 is a new code for optimally dispatching electric power generation portfolio in the country with the dual objectives of improving energy efficiency and reducing environmental pollution. The ESGD is substantially different from the competitive market in the developed economies, the traditional economic dispatching or the rational dispatching principle implemented in China prior to the new policy. This paper develops a hybrid method that integrates the extended priority list (EPL), the equal incremental principle (EIP) and a heuristic method to optimize daily generation schedules under ESGD. The EPL is presented to search desirable units set that satisfies the complicated duration period requirements based on thermal unit generation priority list. The EIP is developed to allocate load among the committed units within the combined set. A heuristic method is proposed to deal with inequality constraints, which usually result in difficulty for power allocation, and used to improve these results. The algorithm has been embedded into a newly developed decision support system that is currently being used by operators of the Guizhou Province power grid to make day-ahead quarter-hourly generation schedules.

15/00591 A novel approach to hot oil system design for energy conservation

Ataei, A. *et al. Applied Thermal Engineering*, 2014, 66, (1–2), 423–434.

In this paper, a new systematic design methodology was developed for hot oil system by changing arrangement of heat exchanger network from parallel to mixed series/parallel. In recirculating hot oil systems, hot oil from the hot oil generator is supplied to a network of heaters that usually has a parallel configuration. However, reuse of hot oil between different heating duties enables hot oil networks to be designed with series arrangements. This allows better hot oil generator performance and increased heating capacity, both in the context of new design and retrofit. First, the hot oil generator and the hot oil network were examined separately, in order to discuss the nature of hot oil system design. A model of hot oil systems was then developed to examine the performance of the hot oil generator to recirculation flow rate and return temperature, as well as to predict heating efficiency. In second step, the design of the overall hot oil system was developed by investigating the interactions between the hot oil network design and the hot oil generator performance. Debottlenecking procedures for the design of hot oil systems was also developed.

15/00592 A protocol for lifetime energy and environmental impact assessment of building insulation materials

Shrestha, S. S. *et al. Environmental Impact Assessment Review*, 2014, 46, 25–31.

This paper describes a proposed protocol that is intended to provide a comprehensive list of factors to be considered in evaluating the direct and indirect environmental impacts of building insulation materials, as well as detailed descriptions of standardized calculation methodologies to determine those impacts. The energy and environmental impacts of insulation materials can generally be divided into two categories: (1) direct impact due to the embodied energy of the insulation materials and other factors and (2) indirect or environmental impacts avoided as a result of reduced building energy use due to addition of

insulation. Standards and product category rules exist, which provide guidelines about the life cycle assessment (LCA) of materials, including building insulation products. However, critical reviews have suggested that these standards fail to provide complete guidance to LCA studies and suffer from ambiguities regarding the determination of the environmental impacts of building insulation and other products. The focus of the assessment protocol described here is to identify all factors that contribute to the total energy and environmental impacts of different building insulation products and, more importantly, provide standardized determination methods that will allow comparison of different insulation material types. Further, the intent is not to replace current LCA standards but to provide a well-defined, easy-to-use comparison method for insulation materials using existing LCA guidelines.

15/00593 An ultra-low energy method for rapidly pre-concentrating microalgae

Shuman, T. R. *et al. Bioresource Technology*, 2014, 158, 217–224. This study demonstrates that *Nannochloropsis* sp. can be effectively separated from its growth medium (0.2–0.3 g/L) using electro-coagulation–flocculation in a 100 mL batch reactor with nickel electrodes and a treatment time of only 4 s. Minimum energy density input for effective separation is 0.03 kWh/m³. Both energy input and treatment time are much smaller than reported elsewhere. The process results in rapid separation of microalgae (over 90% in 120 min) with minimal damage to algal cells (gt;90% still alive after processing). At around 4 V input, algae can be effectively separated even in very low concentrations. Pulsing is equally effective in separating microalgae as continuous direct current of same magnitude and total exposure time. Algae can separate from their growth medium even if the suspension itself is not treated, but is mixed with treated saltwater with same conductivity. The described method has significant advantages including applicability to continuous processing and water reuse.

15/00594 Assessment of methods to reduce the energy consumption of food cold stores

Evans, J. A. *et al. Applied Thermal Engineering*, 2014, 62, (2), 697–705. Energy is a major cost in the operation of food cold stores. Work has shown that considerable energy savings can be achieved in cold stores. Results from 38 cold store audits carried out across Europe are presented. Substantial savings could be achieved if operation of cold storage facilities were optimized in terms of heat loads on the rooms and the operation of the refrigeration system. Many improvements identified were low in cost (improved door protection, defrost optimization, control settings and repairs). In large stores (>100 m³) most improvements identified were cost effective and had short payback times, whereas in small stores there were fewer energy saving options that had realistic payback times. The potential for large energy savings of at minimum 8% and at maximum 72% were identified by optimizing usage of stores, repairing current equipment and by retrofitting of energy efficient equipment. Often these improvements had short payback times of less than 1 year. In each facility the options to reduce energy consumption varied. This indicated that to fully identify the maximum energy savings, recommendations need to be specific to a particular plant. General recommendations cannot fully exploit the energy savings available and therefore to maximize energy savings it is essential to monitor and analyse data from each facility.

15/00595 Assessment of the economic performance of vacuum insulation panels for housing projects

Cho, K. *et al. Energy and Buildings*, 2014, 70, 45–51. One of the key concerns for achieving a passive house is highly efficient thermal insulating materials. With this in mind, the vacuum insulation panel (VIP) was developed recently to improve heat transmission efficiency. On the other hand, project owners or managers are often reluctant to apply VIPs to their particular housing projects because of the relatively high installation costs compared to conventional panels. Therefore, this paper evaluated the economic performance of VIPs by life cycle cost analysis (LCCA) including the energy costs during the operation phase of the house adopting the VIPs. The results showed that economic benefits can be earned from the installation of VIPs in terms of energy consumption during the operational phase of the house. LCCA for a 40-year period showed that VIP 30T and VIP 20T could provide as much as 136.923% and 88.28% more economic benefit than conventional insulation panels, respectively. These results show that the project owner or manager can choose VIPs as a thermal material for their housing projects even after considering the high installation costs.

15/00596 Calculation method and tool for assessing energy consumption in the building stock

Tuominen, P. *et al. Building and Environment*, 2014, 75, 153–160.

A novel calculation tool (REMA) for assessing the effects of various energy efficiency measures in buildings on the scale of the whole building stock of Finland is presented along with an estimate concerning the most recent changes in the regulation for energy use in buildings. REMA is a bottom-up model that uses representative building types (archetypes) for estimating energy consumption in different segments of the building stock. Future developments are estimated using annual rates of new construction, renovations and removals from the building stock. REMA was used to calculate the development of energy use in the building stock after the latest changes to the Finnish building code. For this purpose, the energy demands of the different standard building types were simulated using the IDA-ICE 4.2 dynamic simulation program. The results show a decrease of about 3% in heating energy consumption to 70.0 TWh and a 6% increase in electricity consumption to 19.7 TWh by the year 2020 corresponding to a reduction of 2% in total energy consumption. For CO₂ emissions, a decrease of about 4% can be expected by 2020 concerning all energy use in the building stock. Over longer periods of time, the pace of reductions is accelerated as the share of new buildings in the stock grows larger.

15/00597 Daylight factor estimation at an early design stage to reduce buildings' energy consumption due to artificial lighting: a numerical approach based on Doehrlert and Box-Behnken designs

Mavromatidis, L. E. *et al. Energy*, 2014, 65, 488–502.

In buildings in the residential and tertiary sectors, daylight issues primarily respond to increasing needs regarding the well-being and visual comfort of occupants as well as to the supply of natural light for working, by decreasing energy consumption due to necessary artificial lighting for the internal human activities. Daylight optimization at an early design stage can be referred to a way of designing architectural forms that take advantage of the prevailing urban context, such as existing shadow masks, to achieve a comfortable interior environment while minimizing energy use and reliance on artificial lighting systems. Past study resulted in the development of EcCoGen, which is a kind of software that belongs to the family of tools based on interactive generative genetic algorithm optimization. The software generates solutions evaluated according to certain criteria, including mainly energy performance issues. Since the energy evaluation is included in the software features, the authors aimed to enhance software's applicability including energy reduction due to lighting issues via visual comfort optimization. Based on this objective, this paper describes a simple methodology to optimize the daylight potential of an architectural form at an early design stage. A numerical approach conducted employing the DIALux 4.5 is presented while a variety of simulation scenarios has been investigated on the basis of Doehrlert and Box-Behnken design of experiments methods. The purpose is to develop accurate enough regression models for daylight factor prediction at an early design stage, when the problem's data are not precisely determined (dimension of glazing area, materials, opacities). To validate this statistical forecast system, many simulation scenarios were carried out and the statistical results are in compliance with the numerical simulations. The regression models' results show that the error caused by simplification is acceptable in most conditions, and a lot of coupling calculation is saved. Finally, a formal error analysis for the resulted regression models has been conducted to validate its forecast capacity. As a conclusion the statistical reduction of complex numerical modelling to simple regression models in the form of polynomial equations aims to assist architects and engineers to directly obtain a high precision estimation of their architectural form's daylight potential at an early design stage.

15/00598 Determination of energy saving and optimum insulation thicknesses of the heating piping systems for different insulation materials

Kayfeci, M. *Energy and Buildings*, 2014, 69, 278–284.

Large heat losses occur in pipelines of district heating systems. A significant energy saving would be obtained if these pipelines were insulated. In this study, by using life cycle cost analysis method, the optimum insulation thickness, energy savings, annual costs and payback period were estimated for various pipe diameters and insulation materials of the heating systems in Isparta in Turkey and in the regions with different degree-day values. Natural gas was used in the study as a fuel. In consequence of the calculations, the optimum insulation thickness was found vary between 0.048 and 0.134 m, the energy-saving was found vary between 10.84 and 49.78 \$/m; and the payback period was found vary between 0.74 and 1.29 years. According to these results, EPS insulation material with a nominal diameter (DN) of 250 mm provides the highest energy savings, while the lowest value was found to be in fibreglass insulation material with a DN of 50 mm. As a result, heating systems, selection of suitable pipe diameters and insulation materials with optimum thicknesses provide significant economic advantages and savings.

15/00599 Energy conservative air conditioning system using silver nano-based PCM thermal storage for modern buildings

Parameshwaran, R. and Kalaiselvam, S. *Energy and Buildings*, 2014, 69, 202–212.

This work aims at improving the thermal performance and energy efficiency of chilled water based variable air volume air-conditioning system integrated with the silver nanoparticles embedded latent thermal energy storage system. The latent thermal energy storage air conditioning system incorporated with the demand controlled ventilation and the economizer cycle ventilation schemes were experimentally investigated for the year-round building air-conditioning application. Phase change material embedded with silver nanoparticles enabled it to exhibit improved heat transfer mechanisms in charging and discharging cycles. Experimental results suggest that the proposed air conditioning system achieved an on-peak and per day average energy savings potential of 36–58% and 24–51%, respectively, for year round operation while compared to the conventional air-conditioning system. Similarly, while compared with a basically similar variable air volume air-conditioning system, the proposed air-conditioning system yielded 7.5–18.6% and 7.9–17.8% of on-peak and per day average energy conservative potential, respectively. Furthermore, test results infer that the combined effects produced by the silver nanoparticles embedded latent thermal energy storage system with the ventilation techniques augmented the overall thermal performance of the system. In total, the combined air-conditioning system would be beneficial in terms of accomplishing good thermal comfort, acceptable indoor air quality and energy redistribution needs in buildings without sacrificing energy efficiency.

15/00600 Energy consumption comparison analysis of high energy efficiency office buildings in typical climate zones of China and U.S. based on correction model

Liu, L. *et al. Energy*, 2014, 65, 221–232.

Actual operation energy consumption of high-energy efficiency buildings built and operated in China and the USA has been unexpectedly different. This paper compares actual energy consumption to predict high energy efficiency office buildings in the USA and China. Considering the different indoor design temperatures, climate conditions and operation periods between the compared cases in the two countries' impacts on the building energy consumption, a correction model was built to eliminate the influence of the three factors on the comparison result and put the comparison analysis of high energy efficiency office buildings in the two countries into the same level. With regard to building general information and climate condition, four pairs of buildings in typical climate zones of China and the USA were selected to compare the building energy conservation technology and building energy consumption based on a large scale of investigation and testing. After correction, the energy consumption data are analysed, including total energy consumption, and sub-metering energy consumption such as heating, cooling, lighting, office equipment, etc. The energy-saving technologies applied in these four pairs of buildings was also compared to explain energy consumption differences.

15/00601 Energy saving in ceramic tile kilns: cooling gas heat recovery

Mezquita, A. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 102–110.

A great quantity of thermal energy is consumed in ceramic tile manufacture, mainly in the firing stage. The most widely used facilities are roller kilns, fuelled by natural gas, in which more than 50% of the energy input is lost through the flue gas and cooling gas exhaust stacks. This paper presents a calculation methodology, based on certain kiln operating parameters, for quantifying the energy saving obtained in the kiln when part of the cooling gases are recovered in the firing chamber and are not exhausted into the atmosphere. Energy savings up to 17% have been estimated in the studied case. Comparison of the theoretical results with the experimental data confirmed the validity of the proposed methodology. The study also evidenced the need to improve combustion process control, owing to the importance of the combustion process in kiln safety and energy efficiency.

15/00602 Energy savings in the hydraulic circuit of agricultural tractors

Borghi, M. *et al. Energy Procedia*, 2014, 45, 352–361.

Increasing interest in reducing pollutant emissions and fuel consumption of off-road vehicles has led to research into alternative systems that aim to reduce the power dissipation of the hydraulic circuits equipping such vehicles. This work proposes alternative hydraulic architectures for agricultural tractors in comparison with traditional systems. The alternative circuit architecture uses independent metering valves and electronically controlled variable pump and involves different control strategies. The analysis is performed with reference to the hydraulic circuit and operating conditions of the remote utilities

of a medium-sized tractor. A duty cycle for remote utilities is used for the analysis, obtained from experimental measurements on a tractor equipped with a front loader. Traditional and alternative architectures are modelled using a lumped parameter approach. In this way it is demonstrated that considerable energy savings can be achieved using the alternative architectures.

15/00603 Evaluation of fenestration specifications in Egypt in terms of energy consumption and long term cost-effectiveness

Mahdy, M. M. and Nikolopoulou, M. *Energy and Buildings*, 2014, 69, 329–343.

The Egyptian Residential Energy Code (EREC) provides specifications and recommendations for the construction of buildings that aim to provide comfort built environment for the occupants. Among these specifications are many dependency relationships between different variables that affect the selection process of the building fenestration. The effect of these variables (window-wall ratio and glass thermal properties) and their associated shading devices (recommended by EREC) on the optimization of energy consumption, as well as its long-term cost-effectiveness, is the main focus of this paper, investigated in three climatic zones in Egypt, under different climate change scenarios. Although these specifications are well defined in EREC, recommendations of the best combinations of these variables (for each climatic zone) do not exist. The findings recommend different combinations of window wall ratios, glass types and associated shading devices according to each climatic zone, to achieve indoor thermal comfort, as well as long-term cost-effectiveness.

15/00604 Experimental assessment of the energy consumption of urban rail vehicles during stabling hours: influence of ambient temperature

Powell, J. P. *et al. Applied Thermal Engineering*, 2014, 66, (1–2), 541–547.

Urban rail has widely recognized potential to reduce congestion and air pollution in metropolitan areas, given its high capacity and environmental performance. Nevertheless, growing capacity demands and rising energy costs may call for significant energy efficiency improvements in such systems. Energy consumed by stabled rolling stock has been traditionally overlooked in the scientific literature in favour of analysing traction loads, which generally account for the largest share of this consumption. Thus, this paper presents the methodology and results of an experimental investigation that aimed to assess the energy use of stabled vehicles in the Tyne and Wear Metro system (UK). It is revealed that approximately 11% of the rolling stock's total energy consumption is due to the operation of on-board auxiliaries when stabled, and investigation of these loads is therefore a worthwhile exercise. Heating is responsible for the greatest portion of this energy, and an empirical correlation between ambient temperature and power drawn is given. This could prove useful for a preliminary evaluation of further energy saving measures in this area. Even though this investigation focused on a particular metro system in a relatively cold region, its methodology may also be valid for other urban and main line railways operating in different climate conditions.

15/00605 Flash evaporation and thermal vapor compression aided energy saving CO₂ capture systems in coal-fired power plant

Zhang, K. *et al. Energy*, 2014, 66, 556–568.

In this paper, flash evaporation and thermal vapour compression are used to reduce heat consumption of CO₂ capture processes and two improved capture systems are proposed. One is the flash evaporator (FE) and thermal vapour compressor (TVC)-aided system, the other is the heated flash evaporator (HFE) and thermal vapour compressor (TVC)-aided system. Analyses are carried out to verify their effectiveness in reducing heat consumption. Compared with the base CO₂ capture system of 108.76 t/h CO₂ capture capacity from a 660 MW coal-fired power unit, the FE-TVC-aided capture system reduces the specific heat consumption from 4.421 to 4.161 GJ/tCO₂, and the specific exergy consumption from 1.368 to 1.275 GJ/tCO₂, the corresponding energy saving and exergy saving are 10.3%, and the plant electric efficiency penalty is decreased from 11.83% to 11.02%, on condition that the CO₂ recovery ratio is set at 90%. Compared with the base CO₂ capture system, the HFE-TVC-aided capture system reduces the heat consumption from 4.421 to 4.057 GJ/tCO₂, and the specific exergy consumption from 1.368 to 1.243 GJ/tCO₂, the corresponding energy saving and exergy saving are 12.5%, and the plant electric efficiency penalty is decreased from 11.83% to 10.80%.

15/00606 Impact of using cool paints on energy demand and thermal comfort of a residential building

Dias, D. *et al. Applied Thermal Engineering*, 2014, 65, (1–2), 273–281. This work studies the impact of using cool paints and/or thermal insulation on the thermal behaviour and energy demand of a residential building. Buildings with thermal characteristics represent-

ing both old and new constructions are considered. The results were obtained using the dynamic computer simulator ESP-r. Recommendations for designers and/or house-owners in terms of deciding the best thermal comfort solution are withdrawn. For a case-study building in Portugal, in the summer, it was found that an increase in roof and façade value of total solar reflectance (TSR) from 50% to 92% reduced the maximum indoor free-float temperature between 2.0 and 4.7°C in old construction (without thermal insulation), and between 1.2 and 3.0°C in new construction (with thermal insulation). This had as a trade-off effect the decrease of the minimum indoor temperature of up to 1.5°C. The results of annual energy demand for heating showed a maximum penalty of about 30% when using cool paints. However, it was demonstrated that the cooling demand almost vanishes, eliminating the need to install air-conditioning devices. The analysis of specific real hot weather time periods showed that the maximum altitude of the sun, which is related to the month of the year, determines the solution that originates the highest temperature reduction. As the maximum sun altitude decreases the cool paints show comparatively better results.

15/00607 Implementation of energy-saving policies in China: how local governments assisted industrial enterprises in achieving energy-saving targets

Zhao, X. *et al. Energy Policy*, 2014, 66, 170–184.

Local governments have replaced the national ministries that are in charge of various industries to become the primary implementer of energy-saving policies in China since 2000. This paper employs a case study-based approach to demonstrate the significance of local governments' policy measures in assisting industrial enterprises with energy-saving activities in China. Based on the longitudinal case of the Jasmine Thermal Electric Power Company, this paper hypothesizes that sub-national governments have played a major role in implementing energy-saving policies in China since the eleventh five-year-plan period. A wide range of provincial and municipal agencies collaborated in implementing five types of policy measures – informational policy, skill building, improved enforcement of central directives, price adjustment, and funding – that reduced barriers to energy saving and motivated active pursuit of energy-saving activities at industrial enterprises. The case study demonstrates how an enterprise and local governments work together to achieve the enterprise's energy-saving target. The authors will investigate the hypothesis of this paper in the context of multiple case studies that they plan to undertake in the future.

15/00608 Integration of energy efficient technologies in UK supermarkets

Ochieng, E. G. *et al. Energy Policy*, 2014, 67, 388–393.

The purpose of this paper is twofold: to determine if the integration of energy efficient technologies in UK supermarkets can determine consumer behaviour, and to establish if such activities can help satisfying the environmental elements of the client's corporate social responsibilities (CSR) in an attempt to create a competitive advantage. A literature review of existing material considered the history and drivers of sustainability, the types of energy efficient technologies and factors concerning CSR and consumer behaviour in relation to the supermarket industry. Interviews with 15 senior store managers were recorded and transcribed. The opinions of the senior store managers were then sought and analysed using qualitative research software NVivo software. Validity of the data was achieved at a later stage through workshops. The results of this paper suggested that there is a definite lack of awareness and knowledge amongst customers regarding energy efficient technologies. From the findings, it was further established that the key driver for retailers who integrate energy efficient technologies is fiscal incentives, although it was suggested some retailers use CSR strategies to report there are environmental achievements it was ultimately found that cost savings were the primary driver.

15/00609 Methods for assessing energy savings in hospitals using various control techniques

Congradac, V. *et al. Energy and Buildings*, 2014, 69, 85–92.

This study considers the assessment of possibilities for increasing energy efficiency in hospitals using various control techniques that are available today. To present the opportunities for energy savings it is necessary to define the ways in which savings can be achieved (control strategies), and then determine the equations by which each method can be described separately, i.e. to calculate the amount of energy that can be saved. At the same time, it is important to take into account the mutual dependence of various methods and provide the maximum support in selecting the preferred methods for achieving the highest efficiency. In this paper, a specific set of management methods is presented and their implementations are shown by utilizing the previously introduced tool for energy demand calculation.

15/00610 Multi-variable optimization of thermal energy efficiency retrofitting of buildings using static modelling and genetic algorithms – a case study

Murray, S. N. *et al. Building and Environment*, 2014, 75, 98–107.

The retrofitting of existing buildings is an area of research that requires development in order to overcome the 'rule of thumb'-based approach currently being undertaken. Simulation-based optimization is one approach that can assist consultant engineers, architects and other professionals who undertake retrofit projects. This paper presents a degree-days simulation technique coupled with a genetic algorithms optimization procedure to propose optimal retrofit solutions. The research is applied to a recently retrofitted case-study building. A comparison between the implemented retrofit solution and the simulation-based optimal solution is included to demonstrate the applicability of the research to real-world situations. This research demonstrates the necessity to carry out analysis of a project before retrofit works commence to ensure an optimal approach is taken in accordance with the project specific criteria.

15/00611 Optimal synthesis of energy supply systems for remote open pit mines

Carvalho, M. *et al. Applied Thermal Engineering*, 2014, 64, (1–2), 315–330.

The primary motivation underlying the proposal of polygeneration systems for mine sites is to increase the efficient use of natural resources by combining different technologies and energy resources while satisfying energy service demands. For many mineral producers, particularly in Canada's mining extremes of climate and depth, energy in support of mineral production can be the second largest cost centre after labour. A generic methodology is proposed for the design of energy supply systems in mine sites, based on a search for the minimum discounted cost of energy supplied for all feasible different plant configurations. These configurations can be represented within a connectivity matrix which corresponds to a network representation. A mixed integer programming formulation is set out for the multiperiod synthesis and operational planning problem. This is characterized by (i) binary variables for the selection of technologies, (ii) integer variables for the determination of the number of units installed, and (iii) by continuous variables for the representation of energy and economic flows. Through the integration of particular energy supply strategies matching specific mine circumstances (on-grid, remote, degree days, etc.) and consideration of technologies that improve energy efficiency, hitherto not considered new technologies and demand management systems or new perspectives on optimal mine site energy supply can be investigated. Some of these investigations identify the economic conditions through which biomass energy feedstocks should be used, for direct heat production, for gasification and providing for Fischer-Tropsch syndiesel manufacture. As well as integrating demand from mobile diesel-fuelled plant into an optimization procedure this analysis shows how the techniques can be used to explore economic conditions of threshold prices for biomass (purpose-grown biomass and peat are considered herein) and trucked-in diesel. The methodology also allows for electricity and syngas storage and diesel and biomass bunkering. Within the paper the energy demands for a remote, open pit mining operation located in Northern Ontario are considered as a case study to illustrate the technique and investigations. As expected, for mines close to electricity, natural gas, and diesel distribution infrastructures, the optimal choice is to connect. When a constraint is applied specifying that connection is not possible, as would be for the case exemplified, the optimal choice includes some of the more exotic options for mine site energy supply.

15/00612 Real-time, appliance-level electricity use feedback system: how to engage users?

Chen, V. L. *et al. Energy and Buildings*, 2014, 70, 455–462.

Engage is a rapidly deployable, retrofit energy monitoring system developed for direct support of a novel energy use behaviour investigation and a large-scale deployment in campus apartments. Here, the authors describe the end-to-end system and report results related to web dashboard engagement during a year-long experiment. The objective was to determine user engagement with real-time and easily accessible information about personal energy consumption. Leveraging low-cost components, this system was designed to measure separately appliance plug load, heating and cooling, and lighting electrical load in dense-occupancy building environments. The authors developed and used an open source technology for measurement of plug load and developed signal processing algorithms to significantly improve measurement accuracy. They also developed proxy sensors to measure heating and cooling and lighting. The results indicate that 90% of the dashboard activity was undertaken by 50% of the participants and that website engagement was more likely in mid-day and more effective in combination with email reminders. Energy conservation was achieved when combining the dashboard with public information about energy consumption.

15/00613 The influence of an estimated energy saving due to natural ventilation on the Mexican energy system

Oropeza-Perez, I. and Østergaard, P. A. *Energy*, 2014, 64, 1080–1091.

This paper considers the impact of the extensive use of natural ventilation (NV) in the Mexican residential sector on the Mexican energy system. By integrating a thermal-airflow simulation programme with an energy systems analysis model, the impact on the Mexican energy system of replacing air conditioning, in particular, with natural ventilation to cool residential buildings is determined. It is shown that when, as in Mexico, there is a relatively simple connection between supply and electricity demand, NV creates savings which could be used to reduce either the fossil-fuel-based generation and mitigate CO₂ emissions, or the use of water reservoirs and hydro generation during a dry season.

15/00614 Thermal performance evaluation of bio-based shape stabilized PCM with boron nitride for energy saving

Jeong, S.-G. *et al. International Journal of Heat and Mass Transfer*, 2014, 71, 245–250.

Among the phase change materials (PCMs), bio-based PCMs are considered one of the most promising candidates, due to their large latent heat, low vapour pressure in the melt, good chemical stability, self-nucleating behaviour, safety and commercial availability at low cost. However, the leakage problem and low thermal conductivity of bio-based PCMs limit its application, to some extent. Therefore, porous materials with a high thermal conductivity, such as boron nitride, are promising candidates for simultaneously solving these two problems. In this study, bio-based PCMs were prepared with boron nitride, by using the vacuum impregnation process. The microstructure, chemical bonding, heat capacity, thermal resistance and thermal conductivity of Bio-based PCM with boron nitride, were analysed by scanning electron microscopy, Fourier transform infrared spectroscopy, differential scanning calorimetry, thermogravimetric and TCI analyses. From the analyses, it was expected that bio-based PCM with boron nitride would be useful in applications in various fields, due to its high thermal properties.

15/00615 Ultra high benefits system for electric energy saving and management of lighting energy in buildings

Fathabadi, H. *Energy Conversion and Management*, 2014, 80, 543–549.

This paper presents a smart system, including a multichannel dimmer and a central processor unit (CPU) together with an exact multichannel feedback mechanism, which automatically regulates and manages lighting in buildings. Based on a multichannel luminance feedback, a high benefits technique is utilized to convert the electric energy to lighting energy. Saving a lot of the electric energy which should be converted to lighting energy in buildings, managing the lighting energy in buildings, providing desired constant and adjustable luminance for each room (location), and the capability of working with all AC electric power sources regardless of frequency and voltage amplitude are some advantages of using the proposed system and technique, thus it will be widely used in buildings. An experimental prototype of the proposed smart system has been constructed to validate the theoretical results and to carry out the experimental tests. Experimental results earned by utilizing the proposed smart system in a sample building are presented to prove the benefits of using the system. The experimental results explicitly show a considerable electric energy saving (about 27%) in the sample building while the proposed system has provided the desired constant and adjustable luminance for each location of the building.

17 ENERGY CONVERSION AND RECYCLING

15/00616 Cooling energy efficiency and classroom air environment of a school building operated by the heat recovery air conditioning unit

Wang, Y. *et al. Energy*, 2014, 64, 991–1001.

The recently built school buildings have adopted novel heat recovery ventilator and air conditioning system. Heat recovery efficiency of the heat recovery facility and energy conservation ratio of the air conditioning unit were analytically modelled, taking the ventilation networks into account. Following that, school classroom displacement ventilation and its thermal stratification and indoor air quality indicated by the CO₂ concentration have been numerically modelled concerning the effects of delivering ventilation flow rate and supplying air temperature. Numerical results indicate that the promotion of mechanical ventilation rate can simultaneously boost the dilution of indoor air pollutants and the non-uniformity of indoor thermal and pollutant distributions. Subsequent energy performance analysis demonstrates that classroom energy demands for ventilation and

cooling could be reduced with the promotion of heat recovery efficiency of the ventilation facility, and the energy conservation ratio of the air conditioning unit decreases with the increasing temperatures of supplying air. Fitting correlations of heat recovery ventilation and cooling energy conservation have been presented.

15/00617 Economic feasibility of district heating delivery from industrial excess heat: a case study of a Swedish petrochemical cluster

Morandin, M. *et al. Energy*, 2014, 65, 209–220.

The present work discusses the potential and the economic feasibility of district heating (DH) delivery using industrial excess heat from a petrochemical cluster at the Swedish west coast. Pinch analysis was used for estimating the DH capacity targets and for estimating the cost of heat exchanger installation. A discounted cash flow rate of return of 10% was used as a criterion for identifying the minimum yearly DH delivery that should be guaranteed for a given DH capacity at different DH sales prices. The study was conducted for the current scenario in which no heat recovery is achieved between the cluster plants and for a possible future scenario in which 50% of the fuel currently used for heating purposes is saved by increasing the heat recovery at the site. The competition between excess heat export and local energy efficiency measures is also discussed in terms of CO₂ emission consequences. The maximum capacity of DH delivery amounts today to around 235 MW, which reduces to 110 MW in the future scenario of increased site heat recovery. The results of this analysis show that feasible conditions exist that make DH delivery profitable in the entire capacity range.

15/00618 Energy savings in CO₂ (carbon dioxide) capture using ejectors for waste heat upgrading

Reddick, C. *et al. Energy*, 2014, 65, 200–208.

The biggest technical barrier to full-scale deployment of absorption technology for post-combustion carbon capture in electric power plants is the high energy consumption for solvent regeneration. This paper presents a new application of ejectors to upgrade external waste heat for the purpose of reducing the amount of valuable turbine steam that is required to supply the solvent regeneration process. A shortcut method is proposed to model and optimize a coal-fired post-combustion CO₂ capture process enhanced with ejector driven waste heat upgrading. Although the method can be used for any solvent, monoethanolamine is the reference solvent for this study. The study evaluates the influence of the position of the point of steam injection into the stripper tower, the CO₂ loading of the solvent entering the reboiler from the stripper, the stripper pressure, and the source of the secondary ejector steam. By using the proposed method it is found that the optimal ejector integration allows a 10–25% reduction in the amount of valuable steam. The best results occur when the injected steam is sent to the bottom of the stripper tower, partially replacing the valuable steam from the power plant with waste heat derived steam.

15/00619 Exergy recovery from the exhaust cooling in a DI diesel engine for BSFC reduction purposes

Ghazikhani, M. *et al. Energy*, 2014, 65, 44–51.

In this experimental research, the exergy recovery from a direct injection diesel engine is investigated where a turbocharged OM314 DIMLER diesel engine was tested at various engine speeds (1200, 1400, 1600, 1800 and 2000 rpm) and torques (20, 40, 60, 80 and 100 Nm). For this experiment, a double pipe heat exchanger with counter-current flow is used in the exhaust of the engine. As an important outcome, by increasing the load and engine speed, the recovered exergy increased. Furthermore, the reduction of brake specific fuel consumption (BSFC) due to the use of recovered exergy from exhaust has also been studied in the current study. The results show that by using recovered exergy, BSFC decreased by approximately 10%.

15/00620 Formaldehyde transfer in residential energy recovery ventilators

Hult, E. L. *et al. Building and Environment*, 2014, 75, 92–97.

The rotary enthalpy wheel design used in many energy recovery ventilators (ERVs) is designed to transfer heat and moisture between supply and exhaust air streams. The wheel, however, can also transfer formaldehyde and other indoor contaminants from the exhaust stream to the supply stream through air leakage, entrainment in the porous wheel, and adsorption/desorption to the filter medium. This contaminant transfer reduces the benefit of the mechanical ventilation provided by the device. Field and chamber experiments were used to quantify the formaldehyde transfer efficacy (the fraction of formaldehyde transferred from the exhaust stream to the supply stream) in a common ERV model under varied conditions. In field experiments, the transfer efficacy was approximately 29%. Chamber tests showed formaldehyde transfer efficacy between 10% and 29%. The bulk of the transfer was due to air leakage and entrainment within the wheel, with up to 30% of the transfer attributed adsorption/desorption from the filter medium. The transfer efficacy decreased with increasing air

exchange rate and supply air temperature. The transfer efficacy increased as the supply and exhaust streams were unbalanced in flow rate. Overall, the air leakage through the device substantially exceeded the product rating of 10%, with 27–28% air leakage measured in field experiments and 12–19% air leakage in chamber experiments.

15/00621 Improving heat recovery using retrofitted heat pump in air handling unit with energy wheel

Wallin, J. and Claesson, J. *Applied Thermal Engineering*, 2014, 62, (2), 823–829.

The world is facing a challenge to reduce energy use to meet the environmental goals set for the future. One factor that has a great impact on the energy performance of buildings is the ventilation losses. To handle these losses, heat recovery systems with rotating heat exchanger are often implemented. These systems have been shown to recover about 60–70% of the energy in the exhaust air on an annual basis. After a heat recovery system is installed it is hard to improve the efficiency of the installed recovery system with an acceptable economic payback period. In the present paper one way to improve the energy performance of a building with this type of heat recovery system by the use of a heat pump is investigated by simulations in TrnSys. The heat pump system is arranged so that the evaporator is connected to a heat exchanger mounted in the exhaust airstream after the energy wheel, and the condenser of the heat pump is mounted so that the temperature of return water from the heating coil is increased. The simulations show that there is a possibility to increase the heat recovery rate of the air handling unit in a significant way by retrofitting a heat pump to the system.

15/00622 Kinetic energy recovery system for sailing yachts: preliminary experimental results

Leo Guizzi, G. *et al. Energy Procedia*, 2014, 45, 799–808.

SEAKERS (SEA Kinetic Energy Recovery System) is a research project, funded within the seventh European Union framework programme, whose goal is to develop an innovative device consisting in a model of a kinetic energy recovery system for sailing yachts, based on the conversion of wave-induced boat oscillations (heave, pitch and roll) into electric energy by means of a linear generator. The device aims at recovering as much kinetic energy as possible from the natural movements of a sailing yacht on the sea, therefore taking the view of a boat as a moving wave energy converter with energy harvesting capability. The boat's motions can be vertical oscillations due to the buoyancy in the presence of sea waves and rolling and pitching motions originated both by sailing in wavy waters and by the normal boat dynamics due to the sails' propulsion. This paper presents a brief description of the prototype of linear generator, which has been developed in the SEAKERS project, and reports about the first experimental tests carried out on the prototype. Two kind of tests have been performed on the generator, which can be classified as a linear permanent magnet switched reluctance generator: first, the possibility to use the prototype like an actuator has been investigated, in order to force the cursor to have a motion in phase with the external forcing, so as to recover more energy when the machine acts as generator. The behaviour of the actuator was examined in a static way, measuring the forces between cursor and stator, varying relative position of cursor and current in the coils. The second kind of tests has been performed to analyse the efficiency of the generator, for different external loads and translational velocities. The trend shown in these tests are then explained by an analytical model based on an electromagnetic circuit.

15/00623 Mechanical energy recovery from low grade thermal energy sources

Cipollone, R. *et al. Energy Procedia*, 2014, 45, 121–130.

An ORC based power plant for waste heat recovery in stationary applications has been developed and experimentally characterized. The aim of the study was to investigate the performance of a sliding vane rotary expander as the device to convert the enthalpy of the working fluid, namely R236fa, into mechanical and electric energy. A theoretical model of the expander supported the design and allowed to assess the thermodynamic transformations that take place in it. Furthermore, a deep experimental campaign explored the behaviour of the expander and the one of the recovery system also at off design conditions. The experimental activity on the expander included the reconstruction of the indicated diagram using a set of high frequency piezoelectric pressure transducers that provided an accurate prediction of the pressure evolution inside the cell. The overall cycle efficiency achieved was close to 8% and further improvements concerned to the expander design have been addressed. The temperature of the upper thermal source at around 120 °C and the mechanical output power close to 2 kW make the expander and the whole system suitable for plenty of potential recovery applications.

15/00624 Optimal design of inter-plant waste energy integration

Hipólito-Valencia, B. J. *et al. Applied Thermal Engineering*, 2014, 62, (2), 633–652.

In this paper, a new superstructure for heat integration of an eco-industrial park is proposed. Intra- and inter-plant heat exchange for the process streams is allowed. For a proper reuse of the waste heat at low temperature, a set of organic Rankine cycles (ORCs) can be integrated inside the eco-industrial park. This way, the proposed superstructure allows proper heat integration to reduce the use of external cooling and heating utilities as well as the consumption of external electric energy. The proposed superstructure is modelled through a mathematical programming formulation where the objective function considers the simultaneous minimization of the operating and capital costs for the units involved in the system as well the possible revenues from the sales of electricity. The model is formulated in such a way that avoids numerical complications during its solution. Results from the application of the proposed approach show that the interplant-integration offers significant savings compared to the traditional single-plant integration with and without considering ORCs.

15/00625 Parametric study of the alkali catalysed transesterification of waste frying oil for biodiesel production

Al-Hamamre, Z. and Yamin, J. *Energy Conversion and Management*, 2014, 79, 246–254.

Waste frying oil (WFO) conversion to biodiesel by alkali-catalysed transesterification was studied. The effect of operating and processing variables e.g. reaction temperature, MeOH/oil ratio, type of catalyst used and its concentration was investigated at different reaction times. Further, the physical and chemical properties of the WFO and the produced methyl ester (biodiesel) were measured. Results showed that (within the range of variables studied) the optimum conditions for biodiesel manufacturing were MeOH/oil ratio 0.4 v/v (corresponds to 9.5 M ratio), with 1.0% (% w/v) KOH (corresponds to 0.83% w/w), temperature of 50 °C and reaction time between 20 and 40 min. Under these conditions, the obtained Biodiesel yield was approximately 98%. Results also showed that the viscosity of the obtained biodiesel was 5.86 mm²/s which is close to that of petrodiesel with an average decrease of 69.5% in comparison with WFO. Furthermore, the iodine value (25.36 g I₂/100 g sample) and the density (0.877 g/cm³) of the biodiesel met the values specified by JUS EN14214.

15/00626 Performance analysis of waste heat recovery with a dual loop organic Rankine cycle (ORC) system for diesel engine under various operating conditions

Yang, F. *et al. Energy Conversion and Management*, 2014, 80, 243–255.

To take full advantage of the waste heat from a diesel engine, a set of dual loop organic Rankine cycle (ORC) system is designed to recover exhaust energy, waste heat from the coolant system, and released heat from turbocharged air in the intercooler of a six-cylinder diesel engine. The dual loop ORC system consists of a high-temperature loop ORC system and a low-temperature loop ORC system. R245fa is selected as the working fluid for both loops. Through the engine test, based on the first and second laws of thermodynamics, the performance of the dual loop ORC system for waste heat recovery is discussed based on the analysis of its waste heat characteristics under engine various operating conditions. Subsequently, the diesel engine-dual loop ORC combined system is presented, and the effective thermal efficiency and the brake specific fuel consumption (BSFC) are chosen to evaluate the operating performances of the diesel engine-dual loop ORC combined system. The results show that, the maximum waste heat recovery efficiency of the dual loop ORC system can reach 5.4% under engine various operating conditions. At the engine rated condition, the dual loop ORC system achieves the largest net power output at 27.85 kW. Compared with the diesel engine, the thermal efficiency of the combined system can be increased by 13%. When the diesel engine is operating at the high load region, the BSFC can be reduced by a maximum of 4%.

15/00627 Power generation using waste heat recovery by organic Rankine cycle in oil and gas sector in Egypt: a case study

Khatita, M. A. *et al. Energy*, 2014, 64, 462–472.

The organic Rankine cycle (ORC) is a promising technology for the conversion of heat into useful work. This study uses the ORC in an existing gas treatment plant in Egypt, as a case study, to recover the waste heat and convert it into electricity. A simulation model using Aspen HYSYS v7.1 has been built for the case study. Two different cycles, the basic and the regenerative cycles, have been studied. Various working fluids have been investigated using different parameters such as net work produced, efficiency, volumetric flow rate and the irreversibility. To be more confident about the best working fluid, a capital cost and profitability analysis has been performed for the most

two promising working fluids. The simulation has shown that a regenerative cycle using either benzene or cyclohexane is the most promising choice. However, the capital cost and profitability study has shown that benzene is more suitable as working fluid than cyclohexane. Finally, an optimization study on the parameters indicates that the turbo expander inlet pressure of 4.1 MPa and temperature of 290–300 °C are the most appropriate working conditions.

15/00628 Production, characterization and fuel properties of alternative diesel fuel from pyrolysis of waste plastic grocery bags

Sharma, B. K. *et al. Fuel Processing Technology*, 2014, 122, 79–90.

Pyrolysis of high-density polyethylene waste grocery bags followed by distillation resulted in a liquid hydrocarbon mixture with average structure consisting of saturated aliphatic paraffinic hydrogens (96.8%), aliphatic olefinic hydrogens (2.6%) and aromatic hydrogens (0.6%) that corresponded to the boiling range of conventional petroleum diesel fuel (#1 diesel 190–290 °C and #2 diesel 290–340 °C). Characterization of the liquid hydrocarbon mixture was accomplished with gas chromatography–mass spectroscopy, infrared and nuclear magnetic resonance spectroscopies, size exclusion chromatography, and simulated distillation. No oxygenated species such as carboxylic acids, aldehydes, ethers, ketones, or alcohols were detected. Comparison of the fuel properties to the petrodiesel fuel standards ASTM D975 and EN 590 revealed that the synthetic product was within all specifications after addition of antioxidants with the exception of density (802 kg/m³). Notably, the derived cetane number (73.4) and lubricity (198 µm, 60 °C, ASTM D6890) represented significant enhancements over those of conventional petroleum diesel fuel. Other fuel properties included a kinematic viscosity (40 °C) of 2.96 mm²/s, cloud point of 4.7 °C, flash point of 81.5 °C, and energy content of 46.16 MJ/kg. In summary, liquid hydrocarbons with appropriate boiling range produced from pyrolysis of waste plastic appear suitable as blend components for conventional petroleum diesel fuel.

15/00629 Sustainability assessment of renewable power and heat generation technologies

Dombi, M. *et al. Energy Policy*, 2014, 67, 264–271.

Rationalization of consumption, more efficient energy usage and a new energy structure all need to be achieved in order to shift the structure of energy system towards sustainability. The required energy system is among others characterized by intensive utilization of renewable energy sources (RES). RES technologies have their own advantages and disadvantages. Nevertheless, for the strategic planning there is a great demand for the comparison of RES technologies. Furthermore, there are additional functions of RES utilization expected beyond climate change mitigation, e.g. increment of employment, economic growth and rural development. The aim of the study was to reveal the most beneficial RES technologies with special respect to sustainability. Ten technologies of power generation and seven technologies of heat supply were examined in a multi-criteria sustainability assessment frame of seven attributes which were evaluated based on a choice experiment survey. According to experts the most important characteristics of RES utilization technologies are land demand and social impacts, i.e. increase in employment and local income generation. Concentrated solar power, hydropower and geothermal power plants are favourable technologies for power generation, while geothermal district heating, pellet-based non-grid heating and solar thermal heating can offer significant advantages in case of heat supply.

15/00630 Thermodynamic analysis of a low-pressure economizer based waste heat recovery system for a coal-fired power plant

Wang, C. *et al. Energy*, 2014, 65, 80–90.

A low-pressure economizer (LPE)-based waste heat recovery system for a coal-fired power plant (CFPP) is investigated thermodynamically. With the installation of LPE in the flue before the flue gas desulfurizer (FGD), the heat contained in the exhaust flue gas can be recovered effectively and the water consumption can be reduced in the FGD resulted from the temperature lowered flue gas. The impacts on the related apparatuses after installing LPE in a CFPP are analysed and the internal relationships among correlated parameters are presented. The efficiencies of LPE installed in a CFPP evaluated by the first law, the second law and the thermal equilibrium efficiencies are also compared and analysed. A detailed case study based on a 350 MW CFPP unit is presented and the variations of the thermal performance after the installation of LPE are investigated. The results show that the second law and the thermal equilibrium efficiencies are increased which can be indicators to evaluate the performance of the LPE system while the first law efficiency is decreased after installing LPE. Results also show that the saving of standard coal equivalent (SCE) is 3.85 g/(kWh) for this CFPP unit under full load after installing LPE.

15/00631 Thermodynamic analysis of a low-temperature waste heat recovery system based on the concept of solar chimney

Chen, K. *et al. Energy Conversion and Management*, 2014, 80, 78–86. The utilization of low-temperature waste heat draws more and more attention due to serious energy crisis nowadays. This paper proposes a low-temperature waste heat recovery system based on the concept of solar chimney. In the system, low-temperature waste heat is used to heat air to produce an air updraft in the chimney tower. The air updraft propels a turbine fixed at the base of the chimney tower to convert waste heat into electricity. The mathematical model of the system is established based on first law and second law of thermodynamics. Hot water is selected as the representative of low-temperature waste heat sources for researching. The heat source temperature, ambient air temperature and area of heat transfer are examined to evaluate their effects on the system performance such as velocity of updraft, mass flow rate of air, power output, conversion efficiency, and exergy efficiency. The velocity of air demonstrates a better stability than the mass flow rate of air and the pressure difference when temperature of heat source, ambient air temperature or area of heat transfer changes.

15/00632 Thermodynamic analysis of an organic Rankine cycle for waste heat recovery from gas turbines

Carcasci, C. *et al. Energy*, 2014, 65, 91–100.

The use of an organic Rankine cycle (ORC) is a promising choice for the recovery of waste heat at low and medium temperatures. In fact, the low temperature heat discharged in several industrial applications cannot be recovered with a traditional bottoming steam cycle but, using an ORC, this waste heat can be converted into electrical energy. The choice of the fluid is fundamental for a good cycle performance because the optimal thermophysical properties depend on the source temperature. This study illustrates the results of the simulations of an ORC combined with a gas turbine in order to convert the gas turbine waste heat into electrical power. A diathermic oil circuits interposed between these two plants for safety reasons. This paper presents a comparison between four different working fluids in order to identify the best choice. The selected fluids are: toluene, benzene, cyclopentane and cyclohexane. The design is performed by means of a sensitivity analysis of the main process parameters and the ORC is optimized by varying the main pressure of the fluid at different temperatures of the oil circuit; moreover, the possible use of a superheater is investigated for each fluid in order to increase electrical power.

15/00633 Thermodynamic and thermoeconomic analyses of seawater reverse osmosis desalination plant with energy recovery

El-Emam, R. S. and Dincer, I. *Energy*, 2014, 64, 154–163.

This paper investigates the performance of a reverse osmosis (RO) desalination plant at different seawater salinity values. An energy recovery Pelton turbine is integrated with the desalination plant. Thermodynamic analysis, based on the first and second laws of thermodynamics, as well as a thermo-based economic analysis is performed for the proposed system. The effects of the system components irreversibilities on the economics and cost of product water are parametrically studied through the thermoeconomic analysis. The exergy analysis shows that large irreversibilities occur in the high pressure pump and in the RO module. Both thermodynamic and thermoeconomic performances of the overall system are investigated under different operating parameters. For the base case; the system achieves an exergy efficiency of 5.82%. The product cost is estimated to be 2.451 \$/m³ and 54.2 \$/MJ when source water with salinity of 35,000 ppm is fed to the system.

15/00634 Waste heat and electrically driven hybrid cooling systems for a high ambient temperature, off-grid application

Horvath, C. *et al. Energy*, 2014, 66, 711–721.

Forward army bases at high ambient temperature off-grid locations require both power and cooling capacity to function properly. Due to the inefficient existing configuration to meet these demands, there are safety and stability issues as each litre of fuel consumed for electrical power must first pass through a complex, hostile network. In place of the conventional configuration composed of an electrical generator set (Genset) and an electrically powered vapour compression system (VCS), utilizing a smaller Genset with a waste heat driven lithium bromide/water (LiBr/H₂O) absorption system (AS) provides a more efficient combined heat and power (CHP) configuration. With design criteria of ambient temperatures up to 51.7 °C, providing up to 3 kW of non-cooling electricity, and 5.3 kW of cooling, these two configurations were simulated in both steady-state and transient conditions. Additionally, the proposed AS's avoid crystallization and have air-cooled heat exchangers unlike conventional AS's which crystallize at high ambient temperatures and have bulky cooling towers. In the transient simulation for the hottest week, results showed fuel savings of 34–37% with the CHP configuration.